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SEPTEMBER-OCTOBER, 1950

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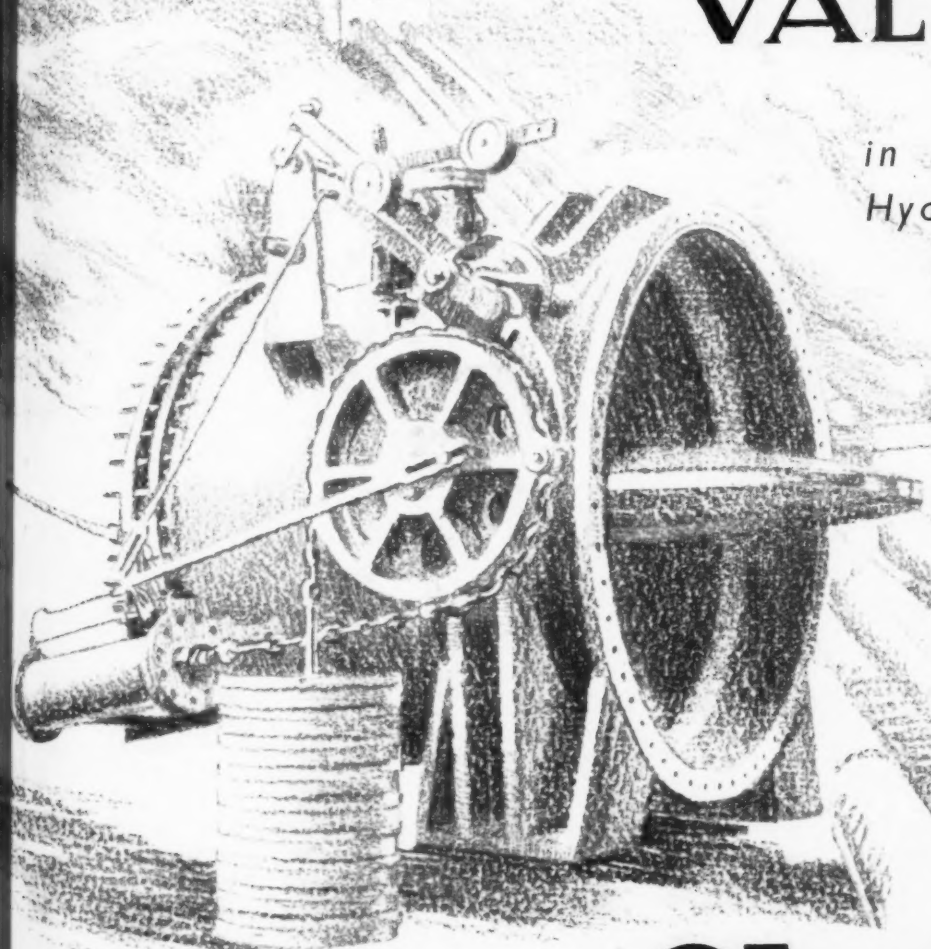

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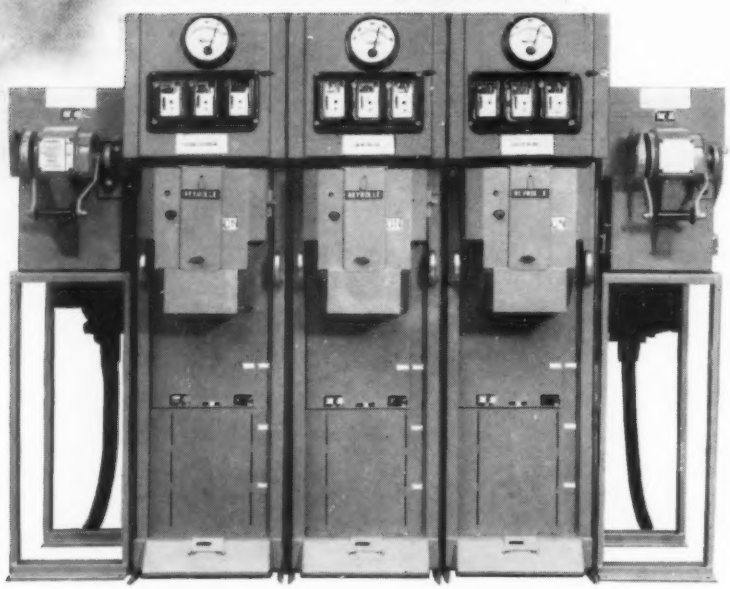

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VOLUME 2. NUMBER 5.

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Published by
Tothill Press Limited,
33 Tothill Street, Westminster, London, S.W.1.
Telegrams: Ishbuilder, Parl, London. Telephone: Whitehall 9233 (12 lines).

MANCHESTER: Century House, St. Peter's Square. Telephone: Central 3101.
BIRMINGHAM: 81 Edmund Street. Telephone: Central 3049.
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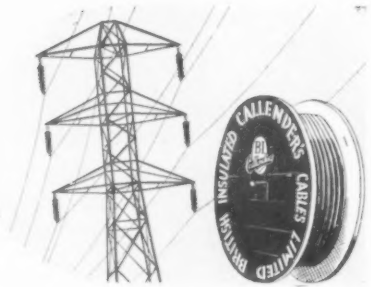

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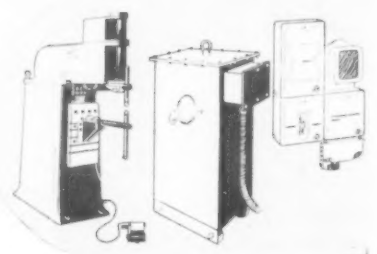

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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Peak Loads

THE opening of the Loch Sloy station on Loch Lomond within 30 miles of Glasgow directs attention to the outstanding advantages of hydro-electric power in meeting peak loads. Sloy has been constructed with this special purpose in mind and has consequently been designed with a higher generating capacity in relation to the water supply than would normally be employed. Within easy reach of the thermally electrified network supplying the industrial belt of Scotland, Sloy, with its ample storage reservoir and high head, is ideally situated to provide current for those peaks which occur, particularly in the winter months, with such disconcerting suddenness. In itself, Sloy will be capable of dealing with peaks of up to 130,000 kW but the fact that it is interconnected with three other hydro-electric stations situated within a radius of 4½ miles, making a combined capacity of 210,000 kW, greatly enhances its usefulness in this respect. Not all this capacity, however, will be available for peak purposes, as some has naturally to provide base load current.

As was pointed out by Mr. A. R. Cooper, Controller of the Merseyside and North Wales Division of the British Electricity Authority, in an article* he contributed to this journal last year, the availability factor of a hydro plant is of the order of 95 per cent. or more while that of a steam plant is rarely in excess of 80 per cent. This may be acclaimed as advantage number one, but it is by no means the most important. In starting up from "cold"—if we can apply this expressive term to a hydro-electric plant—the advantage of water power is even more marked, as the interval required for putting it on full load is conspicuously shorter. At Sloy it is four minutes, while a steam plant of similar capacity would require at least a couple of hours. Moreover, in steam plant provided for peak load conditions much fuel would be required to keep fires banked and the personnel required would be heavier than that for the hydro plant.

In planning a combined steam and hydro-electric system, it is particularly necessary to strike a balance between the power available from each source so that an optimum economic relation can be maintained between the capacity of the base load thermal stations and the hydro-electric peak capacity. In this, of course, water-storage, generating capacity and the seasonal fluctuations in rainfall have to be carefully computed in relation to periods of maximum demand; fortunately, in Scotland, the maximum peaks occur in the winter months and so coincide with the period of maximum rainfall, nature thus assisting in striking a balance. The station will not be required to operate for more than a few hours a day for five days a week so that full advantage can be taken of the liberal storage capacity—1,200 million cu. ft.—created by the new dam, which has converted the former shallow, peaty loch into a vast reservoir of twice the original superficial area and having 160 ft. of effective depth. At one time it was proposed to operate the Sloy scheme as a pump storage basin using eight turbo-alternator pump units having a total capacity of 360,000 kW capacity, utilising thermally generated current at off peak periods to raise water from Loch Lomond back to the Sloy reservoir. This project was abandoned in favour of the present scheme, in which, instead of using the thermal power to supplement the modest natural catchment associated with Loch Sloy, additional high-head water was trapped from a greatly extended area.

As Mr. Cooper stated, the cautious planner will tend to assess the hydro kilowatts on the basis of the driest period ever recorded while the economic planner will veer towards the adoption of a reasonable average and will regard periods of drought or low rainfall as legitimate operational hazards in much the same way as breakdowns of steam plant or distributing systems

*Plant for Peak Load Operation by A. R. Cooper, M.I.E.E., M.Inst.F. March-April issue, 1949, page 81.

are operational hazards. At Sloy it would seem that a midway course has been steered between caution and optimum economy; to this end the capacity and hours of operation have been based on the annual rainfall of 115 to 120 inches whereas in the last few years, during which accurate measurements have been taken on all parts of the catchment, the amount has never been less than 150 inches and has been as high as 180 inches. It would thus appear that normally there is an ample margin to meet all estimated requirements and if a comfortable surplus of water should prove to be available over successive years it can always be used to save coal; there is no necessity for it to be wasted. By a strange coincidence one inch of rainfall at Sloy yields about one million kilowatt hours of electricity and this can be reckoned to be equivalent to about 400 tons of coal—a quite useful supplement to the miners' efforts.

If any criticism should be raised against capital costs it should be remembered that in considering a highly integrated scheme of this kind, peak load plant would have to be provided in any case. In consequence it is only fair to deduct from the hydro scheme the capital cost of a thermal plant of equivalent capacity and availability. In making this computation the extra running costs, depreciation and maintenance charges of the thermal plant should also be taken into account and their capitalised value considered in relation to the hydro plant. No doubt a paper balance could favour the thermal plant but from the practical viewpoint the quick injection of hydro-electric units into a mixed system has imponderable advantages which far outweigh the extra capital involved.

Future Schemes for Scotland

FUTURE SCHEMES under the North of Scotland Hydro-Electric Board are outlined in the report on activities up to the end of last year. Investigations are now advanced for projects to use the waters of Loch Shin, the rivers Orrin, Giorra, Lyon, Lochay, Lednock, Earn and Oude and the Falls of Mucomir. Estimated output of the Shin and supplementary schemes in Sutherland is about 164 million units, and plant capacity about 44,000 kW. Headwaters of the Lyon and Giorra and streams in Glen Lochay and Glen Dochart, Perthshire, probably will be used in a Lyon-Lochay scheme, while the Lednock-Earn scheme is intended to operate on water from the high catchment area between Loch Tay and Loch Earn. The Oude and the Falls of Mucomir schemes are to supply local demands, the Oude in western Argyll near Oban and the Falls of Mucomir near Fort William, Invernesshire. The Shin and Lednock-Earn schemes are due for early promotion. Total output and kilowatt capacity of all schemes—those under construction, those on which work has not begun and those under survey are 1,041,750 kW and 3,017.5 million units.

A Fillip to Industry

A NEW INDUSTRY—the manufacture of large water turbines, has been encouraged in Scotland by the Board. This type of plant, the report records, is now being made for The English Electric Company at the works of Harland and Wolff, Scotstoun, and for Boving and Company at the Clydebank works of John Brown and Co. Ltd., the shipbuilding and engineering firm, and by Glenfield and Kennedy at Kilmarnock. At Alloa the Harland Engineering Company has embarked on water turbine manufacture under American licences and Bruce Peebles and Co., Edinburgh, have extended their manufacturing capacity and are now making water wheel generators of a substantial capacity. Harland and Wolff are also making large electric generators. From the Board itself this new industry has received orders for 895,540 h.p. of water turbines and 368,400 kW of generators. Big orders for export also have come to Scotland, aggregating about 970,000 h.p. of water turbines and 209,000 kW of generators. The normal range of the Glenfield and Kennedy hydraulic manufactures has been extended to include drum gates, a modern type of large automatic spill weir for discharging flood water at dams. Such gates have been installed on dams at Clunie, Pitlochry and Morar.

Costly Developments

TO SATISFY the growing demand for electricity many parts of the Board's distribution network are being strengthened by additional 33,000 volt lines. There is a great amount of distribution development still to be completed in the whole of the Hydro-Electric Board's area, and districts to be served have a sparse and scattered population. The heavy consequent cost of such work means that many years will be required to provide all the supplies needed. One main development ranking high in the list is that of rural areas. Already some progress has been made, but the work can be carried out only at a loss, a fact illuswork can be carried out only at a loss, a fact illustrated in the extent of the Board's area — 21,750 square miles or threequarters of the total area of Scotland and nearly a quarter of the total area of Great Britain. This means that the number of consumers and the revenue to be expected per mile of distribution line are much less in this area than in the rest of the country, but the Board regards the matter as one of great importance for the assistance of agriculture and the economic life of the Highlands.

Profit in 1949

FINANCIALLY the Board reported that the profit for 1949 was £96,815. After deducting the accumulated loss of £74,345 brought forward from 1948 there is a surplus of £22,470 which is carried to the next accounts. Capital expenditure during the year was £13,410,673 and there was an issue of £10 million North of Scotland Electricity Stock.

The Severn Tidal Power Scheme

REPLYING to a recent question in the House of Commons regarding a tidal power scheme in the British Isles, the Minister of Fuel and Power (Mr. Philip Noel-Baker) said that the only scheme of this kind at present envisaged was that based on the Severn Barrage. " Even if the necessary preliminary experiments were complete, it would be difficult, in the present conditions of restricted capital investment, to give it priority over housing and other more pressing needs. This will not, however, always be true (he

continued), and arrangements are, therefore, in hand for the construction of a tidal model of the estuary of the Severn, which is an essential preliminary to the project.

In another answer the Minister said that the British Electricity Authority expected to complete the surveys of all the hydro-electric schemes in North Wales in about a year's time. It should then be possible to give a useful estimate of the capital expenditure which the schemes, if executed, would require.

Welsh Schemes Essential

SUPPORT for the North Wales hydro-electric scheme as a prime means towards the creation of new industries comes from the biggest organisation of workers in the area — the North Wales District Committee of the Confederation of Shipbuilding and Engineering unions. In a letter on the subject to Mr. A. R. Cooper, divisional controller of the British Electricity Authority, the committee is convinced that " the introduction of the scheme will be of inestimable value to the people of Wales in all walks of life." The Electricity Consultative Council for the district has similarly expressed the view that the project will have the important effect of assisting in counteracting the depopulation of the rural areas. The Welsh rural councils, in answer to a questionnaire from the Council for Wales and Monmouthshire on depopulation of the countryside placed electricity at the head of the list of essentials to avert the tendency.

Support for Hydro-Electric Scheme

THE INDUSTRIAL ASSOCIATION of Wales and Monmouthshire is to give full support to the proposed construction of new hydro-electric generating stations in North Wales. Making this announcement after a Council meeting, the Association states that they have heard objections to the scheme as explained by Mr. Clough Williams-Ellis. They have received also an assurance from a representative of the British Electricity Authority with regard to the safeguarding of amenities in North Wales and after careful consideration the Association has decided to inform the British Electricity Authority of its support.

Ontario Forges Ahead

A HIGH POINT in the rapid development of Ontario's vast water power resources was reached with the opening of the three new hydro-electric generating stations during the summer—Tunnel, on the Mississagi River, Pine Portage on the Nipigon, and a section of Des Joachims on the Ottawa. For service to the community in both northern and southern Ontario, well over 200,000 additional horse-power surged through the lines. Before 1950 passes a further 240,000 horse-power will be generated at Des Joachims and 40,000 horse-power at Pine Portage, and by next February production will be enhanced by another 180,000 h.p., of which 60,000 h.p. will come from Chenaux, on the Ottawa River. "One of the greatest publicly-owned utilities in the world " was the description of Ontario's " Hydro " by the Minister of Mines (the Hon. William S. Gemmell). The Hydro-Electric Power Commission is at present in the midst of one of the most costly construction programmes ever undertaken by a public utility. It involves expenditure of 600 million dollars, additional to another 200 million dollars for the conversion of a large section of Southern Ontario from 25- to 60-cycle power. This huge programme is based on an unshakable faith in Ontario's future in mineral development, industry and agriculture.

Queenston's Nearest Rival

WITH all generating units in service the three stations will have a combined capacity of 460,000 kilowatts (approximately 616,500 h.p.). The Des Joachims development, biggest of the three, required the clearing of 11,000 acres of land, the diversion and rebuilding of 23 miles of railway line and 12 miles of highway, and the creation of a great lake—McConnell—extending 57 miles back from the plant. Des Joachims, 35 miles up the Ottawa River from Pembroke, is one of the largest power projects ever undertaken by Hydro, exceeded in capacity only by the Queenston generating station on the Niagara River. With all its eight generating units in service the plant will produce 358,000 kW (480,000 h.p.) at 60 cycles. The power will be transmitted 200 miles over 230,000 volt steel tower transmission lines. At the peak of construction about 2,500 persons were engaged on the project.

A Pyrenees Project

LATEST REPORTS from Spain tell of considerable support for the Ribagirzana hydro-electric project, linked with the river of that name flowing down through the mountains of the north-east many thousands of feet to the plains of Aragon at Lerida. The eleven hydro-electric stations it is planned to establish will ensure the biggest total of electric power in Spain. Much of the water power comes through natural chutes and falls, but it is planned to erect one great dam, 360 feet high, at Escales, high up in the Pyrenees. Other stations will be based on tunnellings down from the San Nicolau lakes. Already a certain amount of power is being produced. When the scheme is completed, probaby eight years hence, it will provide nearly 1,350,000 kWh. Much of the money for equipment has been spent inside the country, but cement plant, purchased from Belgium, is producing 250 tons a day for construction work.

Volta River Survey

THE INTERIM REPORT on the Volta River hydro-electric and irrigation scheme for the Gold Coast is in all probability by now before the Government of the Gold Coast. To a question on the subject by Mr. John Grimston, M.P., in the House of Commons the reply, made on behalf of the Secretary for the Colonies by Mr. Cook, indicated that the Gold Coast Government expected the interim survey about the beginning of August. He could not say, however, when the final report would be available. As indicated in an earlier number of *Water Power* (July-August 1949—page 179) the survey on which the report will be mainly based has special reference to hydro-electric power at Ajena and/or Bui and irrigation of lands bordering the Volta catchment.

Interior of Sloy Power Station

Loch Sloy

A full description of the largest constructional scheme promoted by the North of Scotland Hydro-Electric Board.

Le but premier de ce projet a été de fournir le courant de pointe au réseau industriel d'Ecosse normalement alimenté par des stations thermiques. Les pointes les plus importantes se produisent en hiver au moment des plus grosses pluies; le vaste réservoir d' accumulation de la nouvelle station, la hauteur de sa chute et sa proximité du centre de gravité de la demande industrielle sont d'autres circonstances favorables. Les 4 turbo-alternateurs ont une capacité totale de 130 000 kW.

Este proyecto hidro-eléctrico ha sido primordialmente diseñado para proporcionar corriente en las horas de punta para la red industrial de Escocia, la cual de manera básica es abastecida por estaciones térmicas generadoras de fuerza motriz. Las horas más intensas de punta ocurren en el invierno durante la época de lluvias más copiosas y entre otras circunstancias favorables puede indicarse que la nueva central cuenta con un estanque de almacenaje de agua más que suficiente, un salto de trabajo alto y está cerca del punto de gravedad de la carga industrial. Se llevan instalados cuatro turbo-alternadores dotados de una capacidad total de 130.000 kilovatios.

BESIDES claiming distinction as the largest hydro-electric station in the Highlands and for that matter, in the British Isles, the Loch Sloy project was the first to be promoted by the Board. The work consisted of enlarging a natural high-level loch by a dam 165 ft. high, the augmentation of the catchment area by an extensive series of water courses and tunnels, the driving of a main tunnel to connect the dam with the power station and the construction of a power-station, associated works and pipelines on the shores of Loch Lomond near Inveruglas. This site is within 30 miles of Glasgow so that a transmission line of relatively modest length suffices to convey the energy to the heart of the industrial area of Scotland. Such a factor in itself gives the Sloy station a valuable economic advantage but the outstanding merit of this station is the part it plays in helping the thermal generating stations serving Scottish industries to meet the peak loads which occur in the morning and evening, particularly in the winter months. This aspect of the Sloy station is discussed elsewhere* in this issue.

The Catchment

Before the advent of the power scheme, Glen Sloy, in which the loch is situated, was virtually uninhabited and was entirely without roads. To make operations possible an access road had to be made from Inveruglas to the dam site—a distance of about 2½ miles—and in addition about 15 miles of subsidiary roads were necessary to reach outlying aqueducts, the valve house and other parts of the works. A new railway station was built at Inveruglas and a new bridge had to be erected to take the main road over the tailrace as it enters Loch Lomond.

The natural catchment associated with Loch Sloy is relatively small, being about 6½ square miles—some 20 per cent. of the total catchment that will be available when a system of high-level collecting aqueducts is completed to divert the headwaters of many streams in neighbouring glens into the ample storage area afforded by the new reservoir. These outlying collectors are being constructed in and around the hills to the north and west of Loch Sloy and comprise about eight miles of small-section tunnels and some seven miles of aqueduct. Their disposition will be gathered from the map reproduced in Fig. 1 and it will be seen that they tap the streams flowing into portions of both Loch Lomond and Loch Fine, thus bringing the total catchment area up to 31 sq. miles. This may appear small in relation to the capacity of the generating plant installed, 130,000 kW, but the rainfall is generous, 110 to 180 in. per annum, the storage capacity is extensive and the operating head, 910 ft., is high; also it must be remembered that the station is designed for peak-load purposes and not for continuous running.

The collecting tunnels are rectangular in section, with a curved roof and range in size between 9 ft. by 8 ft. and 6 ft. by 5 ft. and are not lined excepting where they traverse weak rock, when adequate support has been inserted. In driving these outlying tunnels considerable advantage resulted from using Holbits in the drilling operation. Typical sections of the tunnels, the open aqueducts and the circular concrete pipes that it has been desirable to use on occasions where snow and falling debris are likely to cause trouble, are reproduced in Fig. 4. The open channels have the sides battered at 45 deg. and are lined with concrete, and the closed circular sections are of reinforced concrete, ranging from 18 in. to 6 ft. in diameter. In addition there are short stretches of closed, rectangular conduits of reinforced concrete, bridging declivities.

The Dam

The dam across the lower end of Loch Sloy is of the massive buttress type apart from relatively short

* "Peak Loads" (page 181).

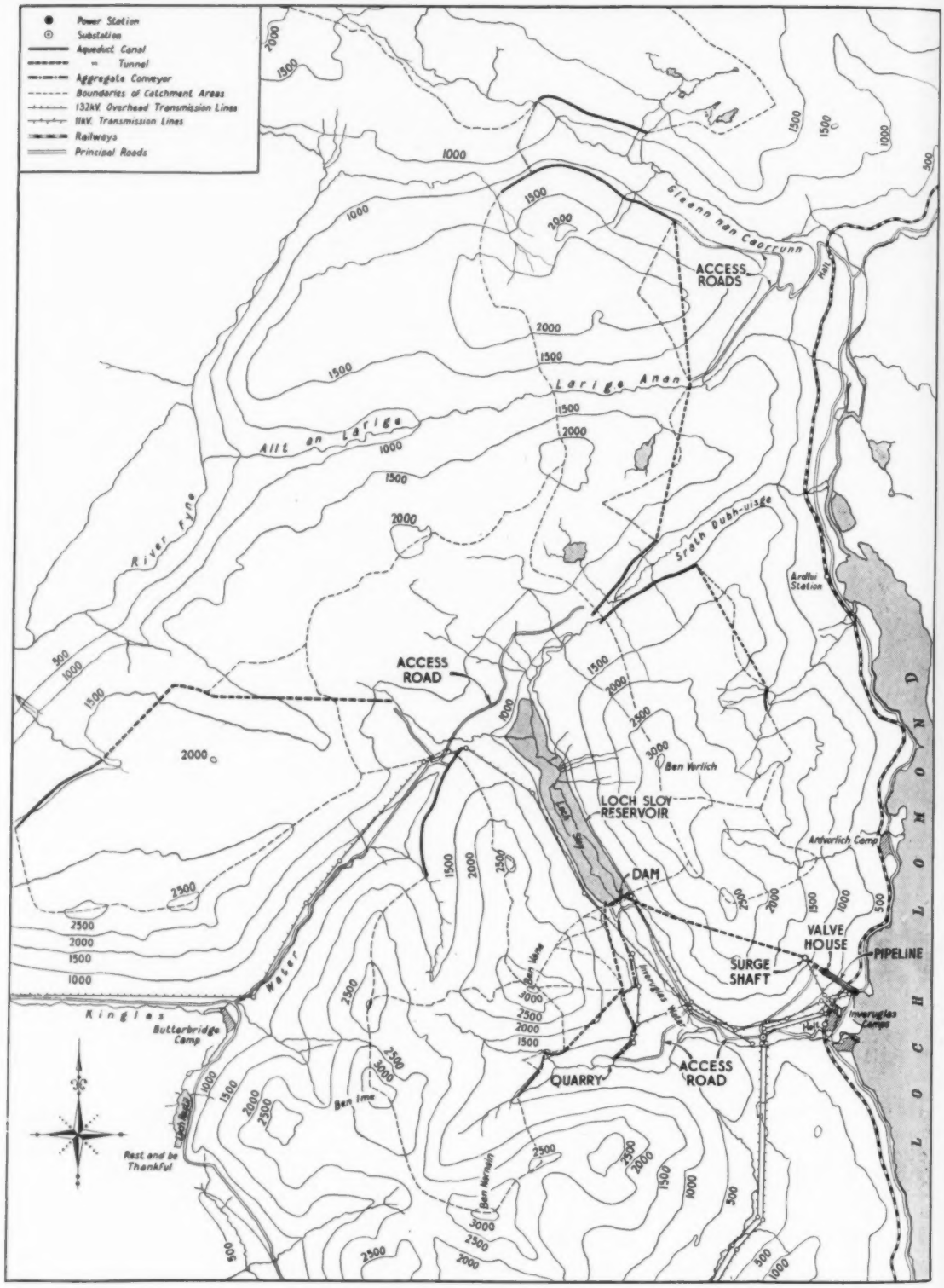

Fig. 1: Diagram, not to scale, showing approximate positions of power station, collecting tunnels and roads

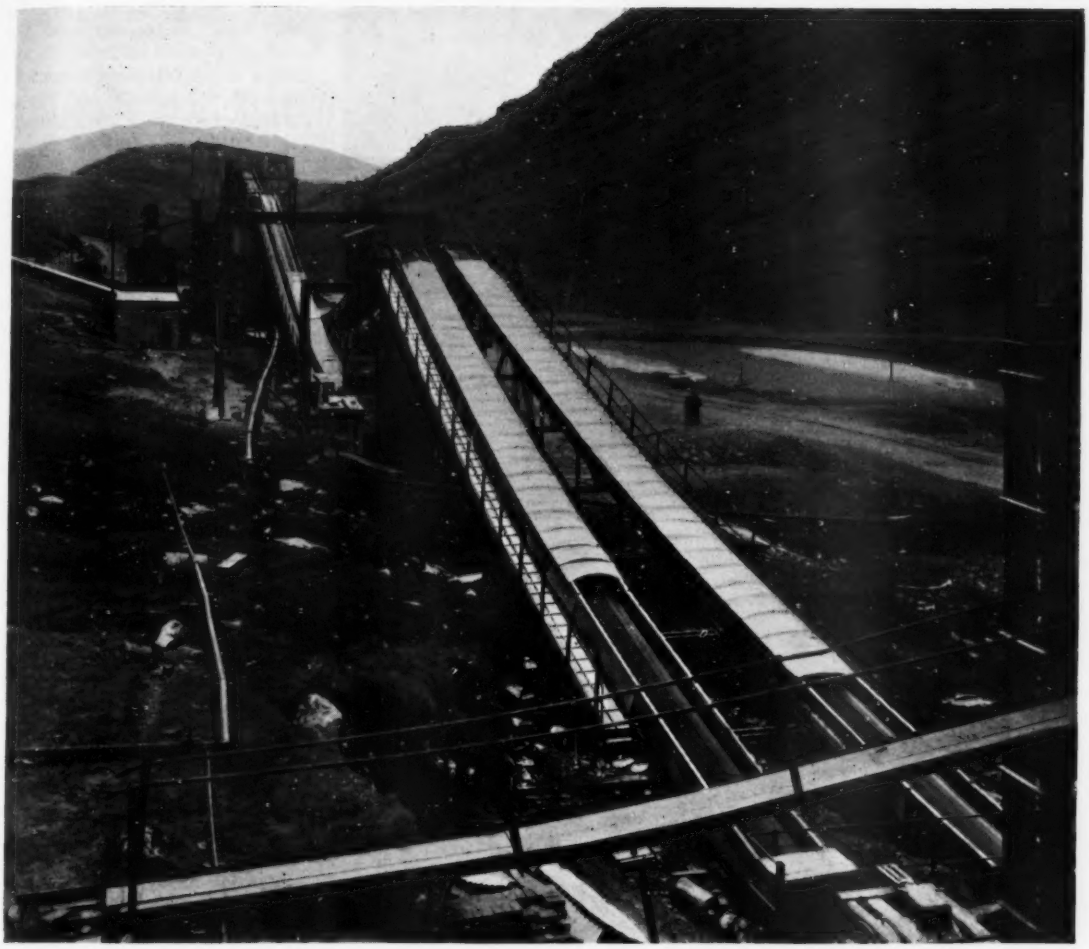

Fig. 2: Conveyors to secondary crushing and screening plant

lengths at the abutments which, like the continuous length of wall which surmounts the top of the arches, are essentially gravity structures. Situated at the east end of the loch the dam is 1,160 ft. long and rises to a height of 160 ft. above the original bed of the stream. It affords accommodation for 1,200 million cu. ft. of water and just about doubles the surface area of the loch which was formerly about a mile long; the surface has been raised by 153 ft. The buttresses are 26 ft. thick, the centres being spaced 65 ft. apart and their downstream slope has a ratio of 1 vertical to 0.8 horizontal. The water facing is sloped at 40 vertical to 1 horizontal and is coated with a bitumastic paint to resist the humic acids derived from the peat.

This wall is arched in elliptical form on the downstream side, between the buttresses, and the buttresses themselves are spanned by arched elements of reinforced concrete which support the concrete gravity structure forming the roadway above the dam proper. The cut-off trench is 10 ft. wide and extends about 10 ft. into the rock abutments, although a pocket of soft material—a glacial giant's kettle containing the typically rounded rock balls—compelled the excavation at one place to proceed to a depth of 60 ft. To provide a spillway, two of the spaces between buttresses on the downstream side are spanned by precast reinforced concrete beams placed edge to edge. At the bottom of the spillway there is a dispersing bucket submerged in a stilling pool. The buttresses are constructed in Tee-form separated by contraction gaps which were filled in later, the adjoining surfaces being keyed and lined with a bitumastic layer before the final concrete filling was inserted. To prevent the development of contraction cracks each buttress was built up in two sections, the Tee head being brought up in stepped form slightly in advance of the stem. Each concrete course corresponded to the steps at the back of the Tee head and was 3 ft. 8 in. deep; it was laid horizontally in the Tee head and on a slope of 1 in 6 in the stem.

For handling the concrete, buckets of 4 cu. yards capacity were used, the laying being assisted by immersion vibrators. Portable, rubber-tyred runabout cranes were used for placing the heavy type formwork used for the concreting and were moved from buttress to buttress by two overhead cableways as necessary.

These two cableways were manufactured and erected by John M. Henderson & Co. Ltd., of Aberdeen, and

Fig. 3: Conveyor line approaching dam site and delivering stone, by means of travelling tripper, to appropriate stock pile

of the work on any part of the site. Each machine is equipped with indicators to show the position of the load in both the vertical and horizontal planes and a telephone is available to afford communication between the driver and the signalman placing the concrete, and *vice versa*. The tail carriages are also controlled from the driver's cabin so that the whole operation of the cableway is controlled by two men, one for each unit. Provision is, of course, made for inching speeds and safeguards are incorporated to prevent accident in the event of overspeeds or any

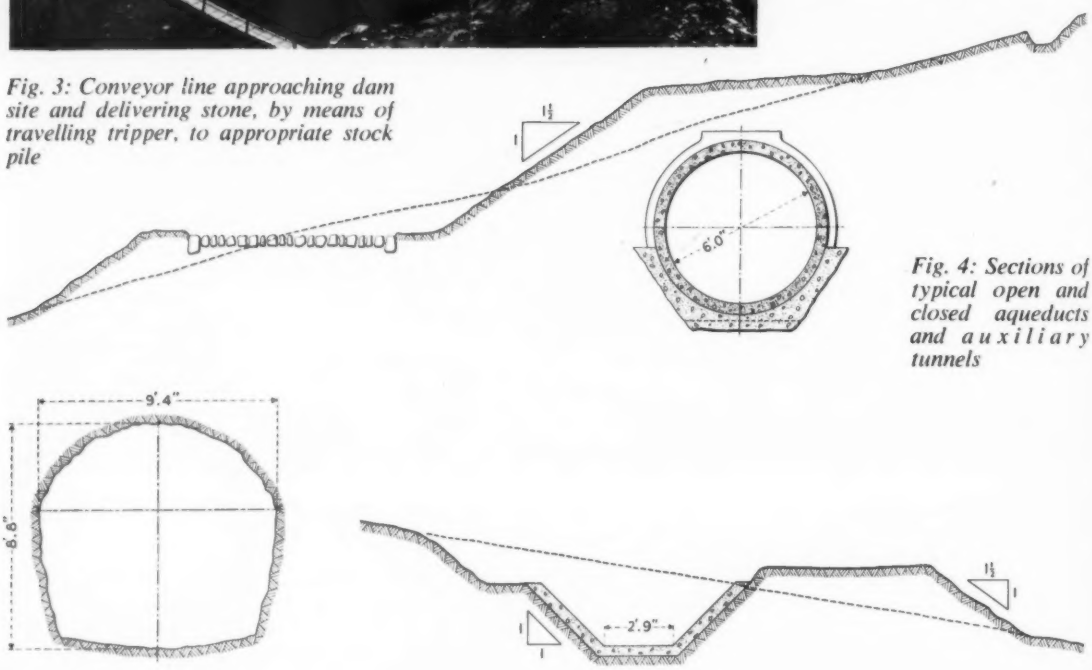

Fig. 4: Sections of typical open and closed aqueducts and auxiliary tunnels

enable practically every part of the site to be reached by the travelling skips which they suspend. Their span is 1,350 ft. and the tail masts, which are mounted on weighted bogey carriages, can be traversed a distance of 150 ft. on radial rail tracks in order to control the placing of the concrete with precision. The two fixed masts on the left bank are 125 ft. high and are guyed at the back and sides by cables connected to fixings embedded in concrete blocks in the hillside. The traversing carriages run on rails set at 25 ft. centres and are electrically operated by remote control. With full load (10 tons) a hoisting or lowering speed of 250 ft. per min. is achieved, the transverse travelling speed being 1,000 ft. per min. A 250 h.p. Bruce Peebles motor is provided on each unit.

Control is effected from an elevated cabin, the windows of which afford the operator a clear view electrical failure, mechanical brakes being automatically applied in either case. The control equipment was supplied by the Igranic Electric Co. Ltd. It should, perhaps, be mentioned that this cableway is the property of the Hydro-Electric Board and will be used on other schemes which the Board will be carrying into completion.

Some 200,000 cu. yards of concrete were used in the dam and as the neighbouring Highland schists were unsuitable for aggregate a quarry had to be opened out at Cairegrogan about 1½ miles away. The rock obtained at the quarry is a tonalite—a quartz-mica-hornblende diorite — having a texture between whinstone and granite and is crushed on the quarry site. It is brought to the dam by a series of troughed belt conveyors which follow a more or less direct route irrespective of irregularities of the ground,

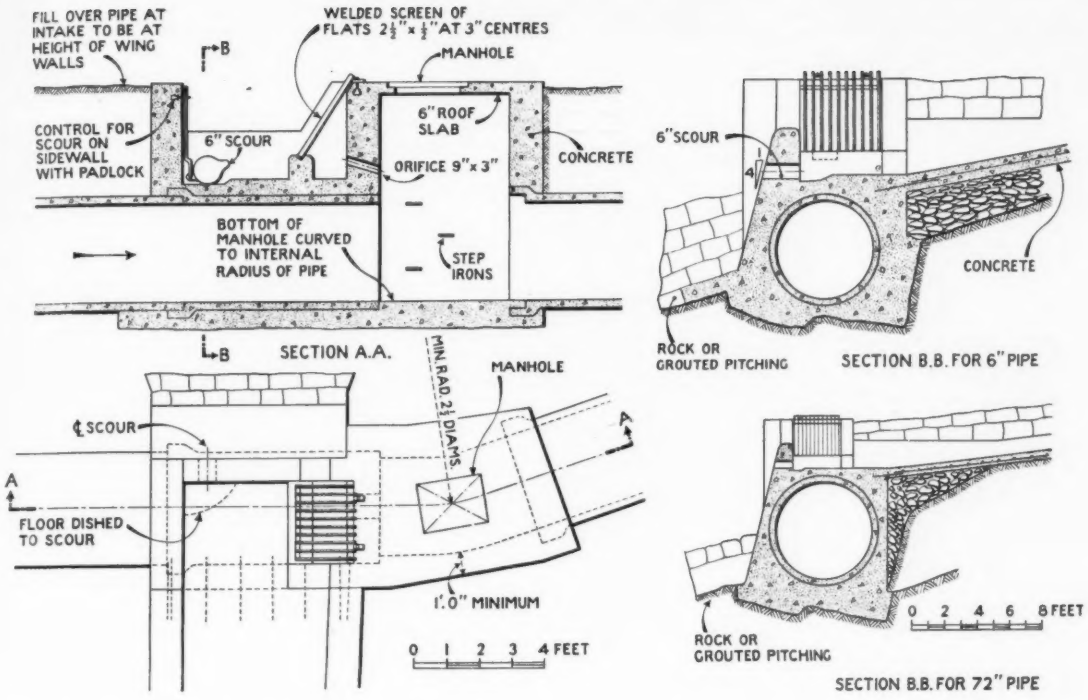

Fig. 5: Drawings showing construction of a typical intake for a feeder aqueduct

timber trestle supports being used to flatten out extreme dips. The belts are 24 in. wide and are electrically driven by motors ranging from 10 to 25 h.p., according to the gradient. The loading station stands at an O.D. of 742 ft. and the first five units, which are relatively short, have an average inclination of 1 in 6½ against the load and rise to the 1,000 ft. contour. The highest point in the route is 1,066 ft. above sea level and from here onwards the load is favourable and the individual conveyors are of correspondingly longer length. The longest section is about 1,400 ft., but as it is favourably inclined at 1 in 22, a 12½ h.p. motor suffices for the drive. For the steep initial sections 25 h.p. motors are necessary.

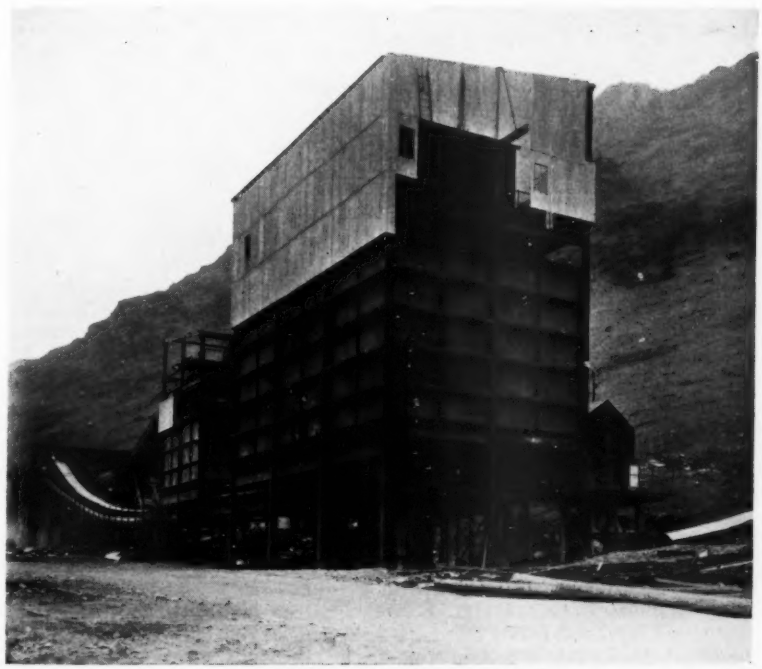

Fig. 6: Storage bunkers and delivery to conveyor line to Loch Sloy

The final section leads to a covered gantry beneath which there is a stockpile capable of storing 3,000 tons. Beneath the stockpile there is a concrete tunnel provided with suitable openings fitted with radial doors; these allow a controlled stream to be discharged to a further troughed belt which conveys the material to the batching plant. On being discharged from the mixers the concrete is loaded into a transfer car and taken to the cableway skips by which it is transported to any desired point on the dam structure Apart from the length between the stockpile and batching plant the whole of the conveying equipment

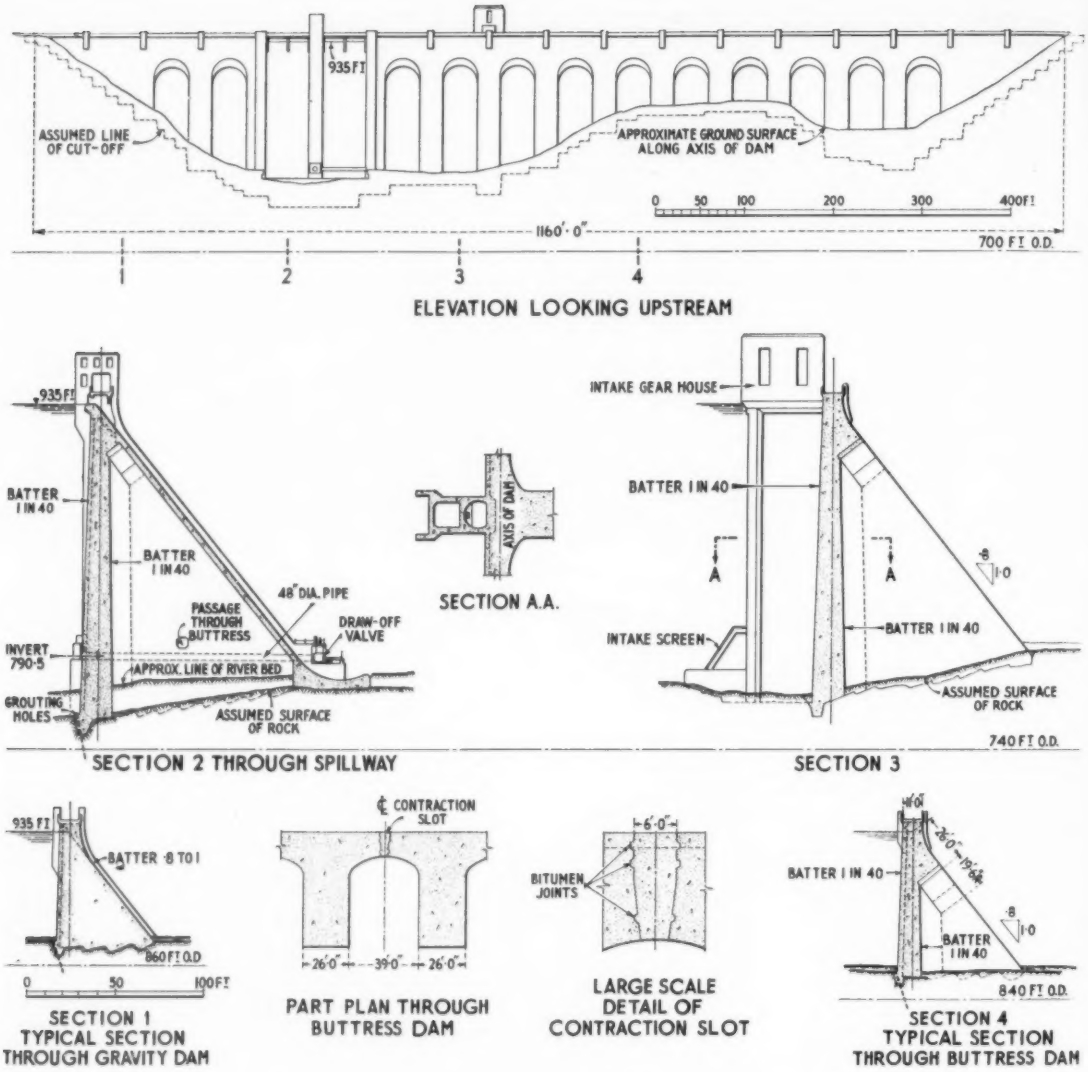

Fig. 7: Elevation of Sloy dam and sections through various points

was supplied by Mavor & Coulson Limited.

The stone is reduced to four sizes and provision is made for mixing these in any predetermined proportions, these grades then being stored at the quarry in bunkers having a capacity of 1,500 tons. Sand has to be brought by barge up Loch Lomond to a wharf near the new power station, being then taken by road lorries to the mixing station at the dam site.

For the mass work an aggregate was used consisting of graded stone containing particles up to 2½ in. in the proportions of 20 cu. ft. to 3½ cwt. of cement and 11 cu. ft. of sand. For the more critical parts of the structure the mix is richer, five bags being used, for instance, in the 2 ft. 6 in. thickness of concrete in the upstream face.

Flow to the main pressure tunnel is controlled from an intake tower surmounting No. 8 buttress, the entrance being protected by a coarse fixed screen followed by a finer lifting screen 25 ft. high by 20 ft. wide. In the latter the 3½ in. by ½ in. section bars are spaced at 3 in. centres and a number of metal trays are attached to the bottom to catch any debris that may fall off when the gate is being lifted. Weighing 15 tons, this screen is suspended by wire ropes and is raised by an electrically driven winch. Wheel tracks serve to guide and steady the screen while it is being raised and lowered—an operation which, of course, is always performed during off-load periods. The intake is of sufficient size to ensure a low velocity of entry but the passage is gradually contracted to accommodate a 19 ft. high by 10 ft. wide guard gate. This is of the tube-rolling type manufactured by Glenfield and Kennedy and is followed by an operating gate of the free-roller type. The maximum load on the guard gate is 1,058 tons and on the operating gate 1,015 tons. It should be understood that the guard gate is used as a reserve and is housed in the gear apartment above the top water level. Its primary

purpose is to shut off the flow and thus allow the valve shaft to be emptied so that the control gate can be inspected and kept in a proper state of repair; but it can also be used in an emergency to shut off the water in, say, the event of other gates or valves failing to operate. It weighs 38 tons and is raised in metal guide grooves by wire ropes wound around an electrically driven winch. Lowering is effected under hand and automatic brake control at a speed of 20 ft. per min.

A counterbalance is provided for the control gate which is housed in the well immediately above the intake opening. Normally it is operated by an electric winch but handgear is available as standby. It is suspended by steel rods attached to a length of Renolds chain which passes over the sprocket wheel of the winch and carries the counterweight. Constructed of mild steel, the gate has a plated face which is strengthened by steel beams connected to the end posts. These posts carry stainless steel track plates for the roller trains which, in turn, bear against the heavy track plates—also of stainless steel—fixed in a heavy Meehanite cast-iron framework set into the concrete. The arrangement of the gates in this way secures several advantages; it not only enables access to be gained by ladders inside the well to the control gate and tunnel when the guard gate is down and the water drawn off, but also provides for the ingress or discharge of air as the tunnel is emptied or filled. Furthermore, when the control gate is cracked open for refilling the tunnel, the well is dry and there is no load on top of the gate—a fact which reduces the opening effort by some 60 tons as compared with a wholly immersed gate on the dam face. In the event of the gate having to be removed it can be hoisted in stages by shortening the suspension rods which have couplings at convenient intervals. A ladder-type gauge to give the water level of the reservoir is attached to the outside of the tower and extends from the top of the intake opening to spillway height. Other water-level gauges are operated by the water pressure and are situated in the power house. These give the pressure readings in front and inside of the intake tower. The difference between these pressures represents the slight loss due to the velocity head and any loss caused by screen resistance and this serves as an indication of when the screens need cleaning.

To empty the reservoir a 4 ft. dia. scour pipe has been inserted in the middle buttress of the spillway, control being obtained by a 3½ ft. dia. Glenfield disperser needle valve. This valve is hand operated, access being gained by a bridge spanning the left bank half of the stilling pool. A protecting screen is provided at the entrance to the scour pipe and also a guard valve which is normally held in a small compartment at the top of the dam. This valve is comprised of heavy free-rolling tubes and sealing tubes carried in a metal frame, and effectively blocks the 5 ft. by 4 ft. opening leading to the scour pipe.

It has been mentioned that the intake entrance is 19 ft. high and 10 ft. wide; downstream from the control gate the rectangular section is gradually merged into a circular section, 13 ft. 6 in. in diameter, consisting of a riveted steel pipe that enters the tunnel proper some 80 ft. distant from the dam face. The pipe passes under one of the buttresses and is laid in a rock trench which was subsequently filled in with concrete.

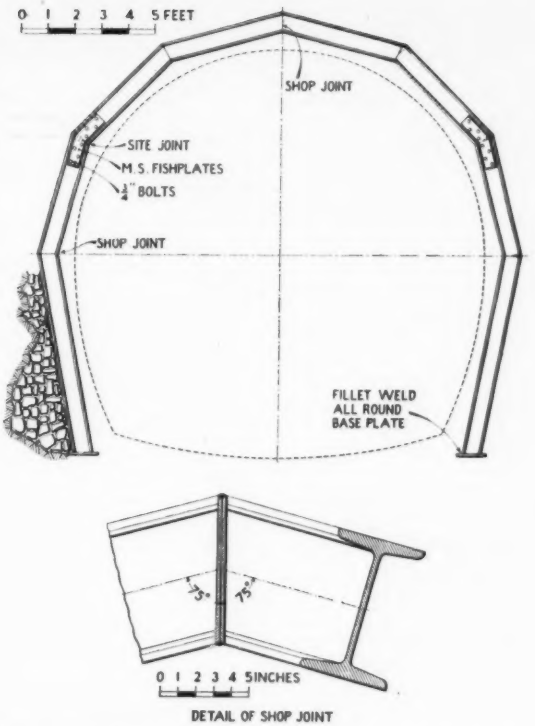

Fig. 8: Arched girder reinforcement used in main supply tunnel

The main tunnel

The main tunnel under Ben Vorlich from the dam to exit near the valve chamber above the penstocks, is 1¾ miles in length. For the most part it is of horseshoe section but is circular to begin with and is lined with concrete reinforced with steel hoops to resist the bursting pressure where the rock cover is shallow. Where the rock cover is sufficient to resist the pressure the circular section is blended into a horseshoe section having a diameter of 15 ft. 4 in. and lined with plain concrete. Reinforcements in the circular section consist of 1½ in. dia. steel bars curved to the circumference of the tunnel and welded at the joints; they are spaced at 6 in. centres and are overlain by 1 in. dia. bars placed longitudinally and spaced around the periphery of the hoops at intervals of 2 ft., 22 bars completing the circle. To allow room for the concreting an extra 3 ft. of rock was excavated from the crown of the tunnel; all the reinforcements were embedded to a minimum depth of 2½ in. on the inside. The tunnel was driven from the outlet end and from an intermediate adit some 800 yards downstream from the dam. The work thus proceeded from three working faces although for a time there were actually four as the circular section was driven from a separate adit near the dam.

Drilling operations were conducted from drill carriages mounting nine hammer drills, 70 holes constituting the round. The holes were 9 ft. deep and each round resulted, on average, in an advance of 7 ft. About 5 lb. of gelignite were used per cubic yard of rock excavated. In the drilling good results were

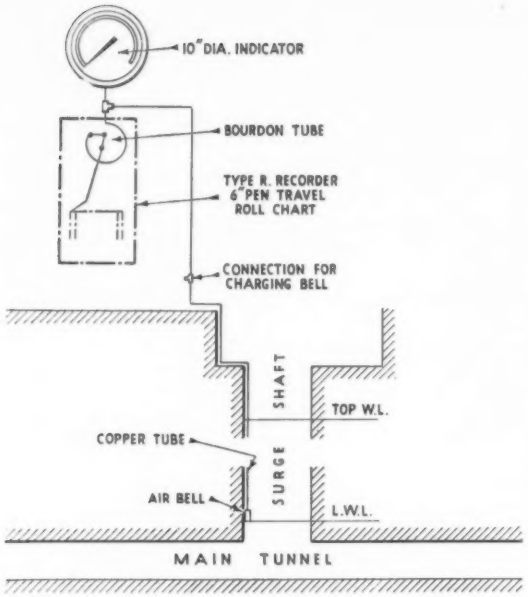

Fig. 9: Diagram showing arrangement of pneumatic type water-level indicator

obtained with cruciform ripbits; up to 250 ft. could be drilled before sharpening became necessary.

Besides the higher efficiency, the detachable bits proved of great convenience in easing the transport problem but unless strict discipline can be enforced the wastage may become excessive as the bits are easily lost and are expensive to replace. Mucking out was accomplished for the main part by Emico shovels and the trains of spoil were hauled to the tips by electric battery and diesel type locomotives.

About 500 ft. back from the downstream portal the horse-shoe section bifurcates into two tunnels each of which is lined with a steel plate piping having an internal diameter of 10 ft. and backed with concrete. After leaving the portals a further bifurcation is effected so that four 7 ft. diameter pipes enter the valve house, whence they continue their way down the steep hillside to supply each of the four turbines.

The surge chamber is situated some 1,000 ft. upstream from the exit portal and consists of a vertical, concrete-lined shaft, 26 ft. in diameter. Horizontal expansion chambers are driven at both the top and bottom to limit pressure variations under the worst conditions when the alternators take up or throw off load. The shaft has a vertical height of 254 ft. above the tunnel invert; the upper chamber is 90 ft. long, 38 ft. wide and 28 ft. high to the crown of the arched roof, while the lower consists of two transverse tunnels, of similar section to the main tunnel and driven from either side of the shaft near the bottom.

Pipelines

The pipelines are 1,500 ft. long and are supported by anchor blocks at four points where an appreciable change of direction takes place. Intermediate supports on curved portions are designed to take care of any lateral thrusts produced by the water pressure. The curvature, which is very slight, is obtained by making mitres at the joints. This was accomplished in the shops by setting up two half cover straps of somewhat smaller diameter than the periphery of the pipe and boring out both ends to the correct angle of the mitre required. The cover straps which, for convenience in erecting, are constructed in two halves, are secured by double or triple riveting according to the thickness of plate used, i.e. $\frac{11}{16}$ in. at the top and $1\frac{9}{16}$ in. at the bottom.

The semicircular halves are shop riveted on adjacent pipes and the only welding needed on site was at the butt joins formed where the ends meet. This construction gives a perfectly smooth internal diameter apart from the slight protrusions formed by the countersunk rivet heads. The internal diameter of the pipes is reduced in progressive steps from 7 ft. at the top to 6 ft. 4 in. at the bottom. They were supplied in 24 ft. lengths and were constructed from three strakes bent to the required radius and electrically welded by machine. All the welding was checked by X-ray photography and the individual 24 ft.

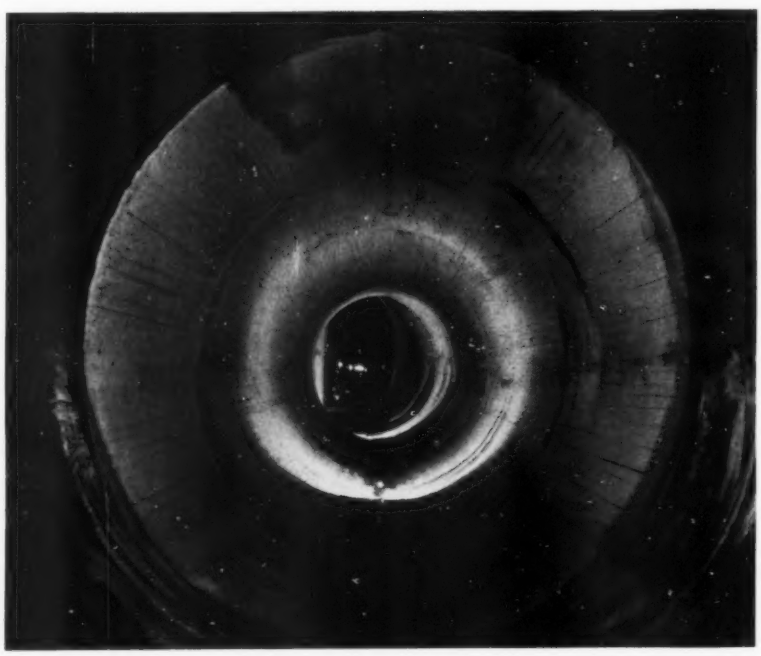

Fig. 10 : Interior of lined, circular portion of Sloy tunnel

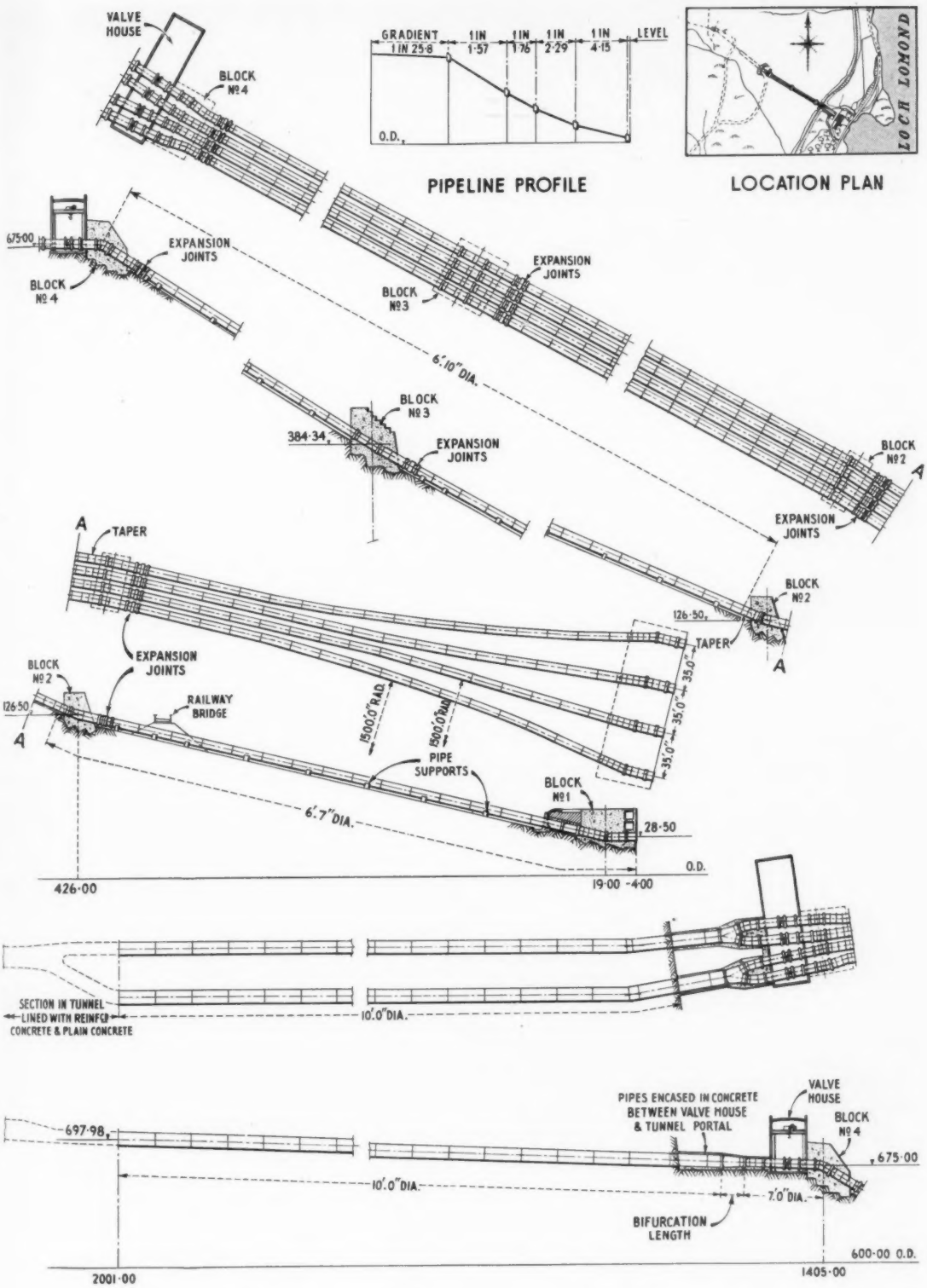

Fig. 11: General arrangement and details of pipelines

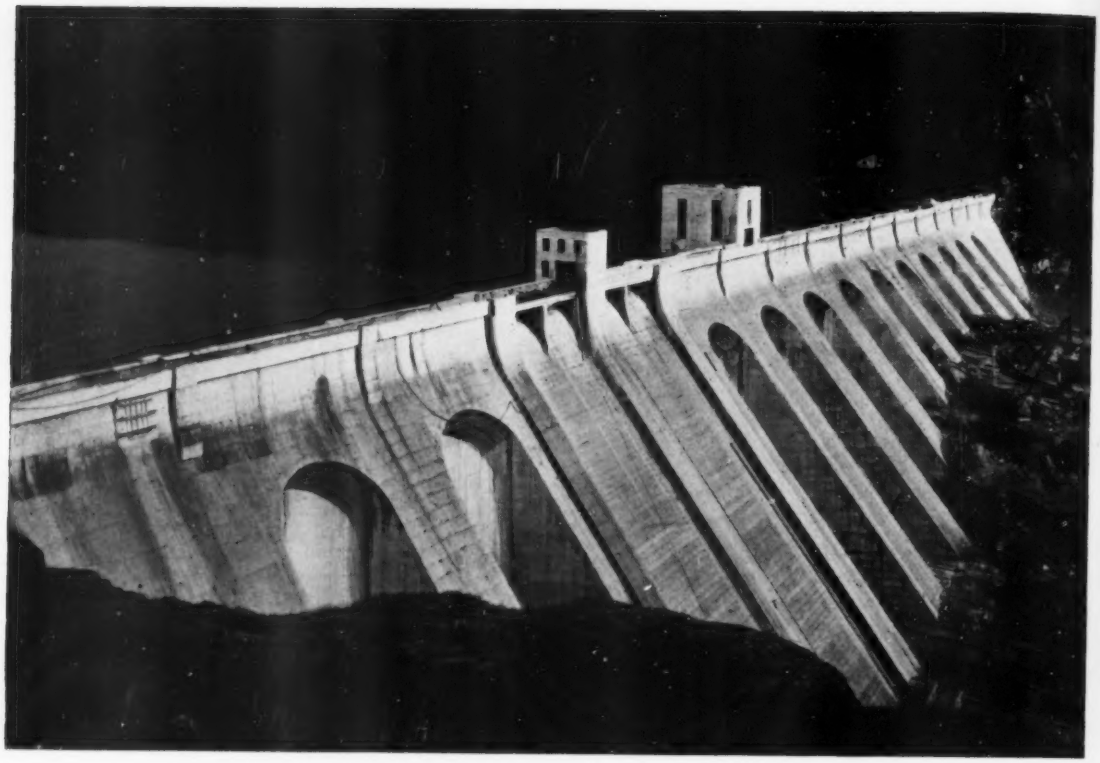

Fig. 12: General view of Sloy dam

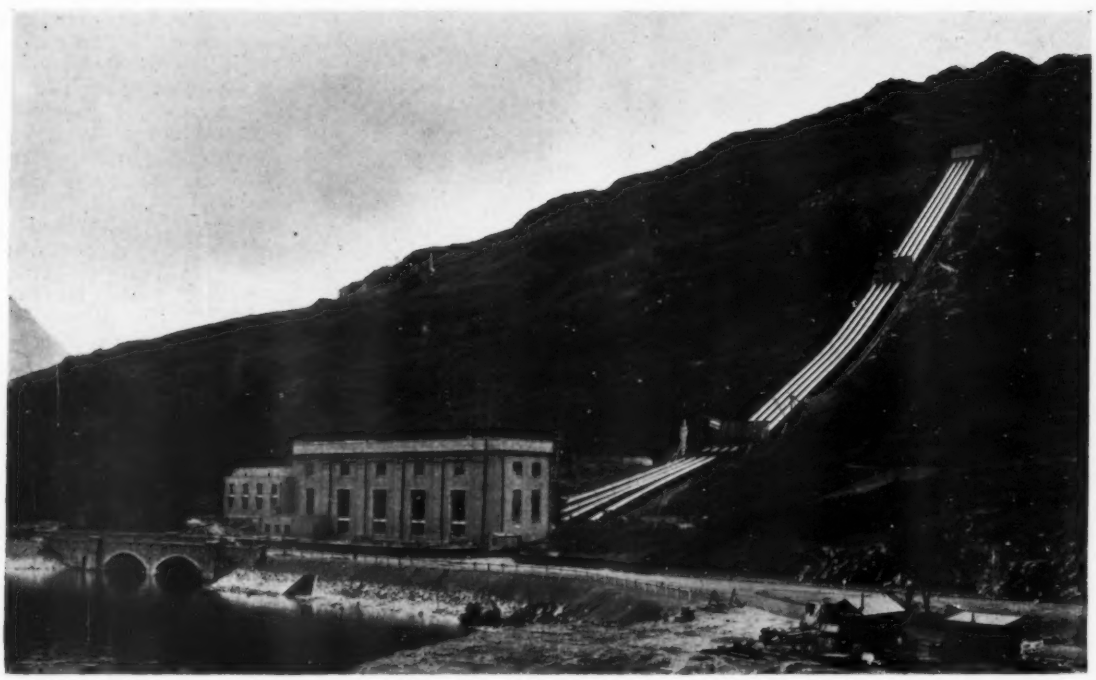

Fig. 13: View of power station showing pipelines

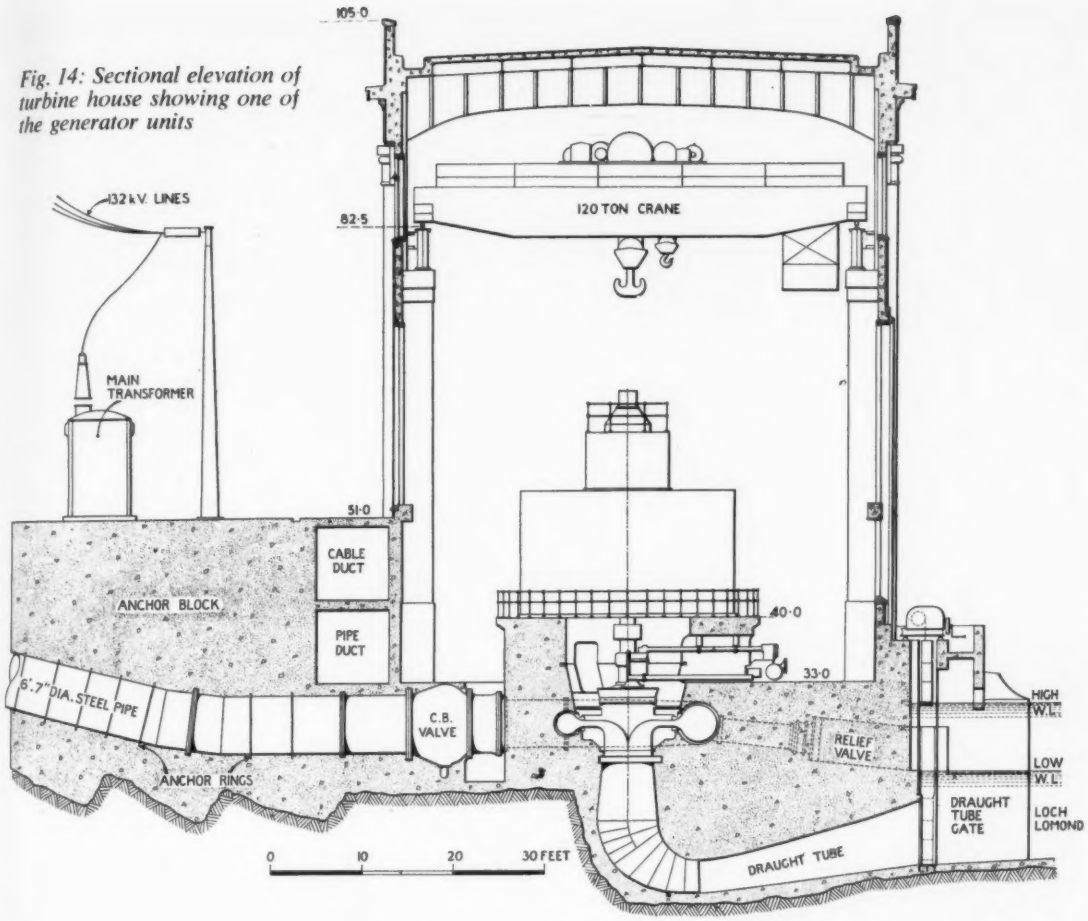

Fig. 14: Sectional elevation of turbine house showing one of the generator units

lengths were tested hydraulically to 50 per cent. above any water-hammer pressures that could conceivably be developed. These test pressures ranged up to 750 lb. per sq. in. for lower sections and it is understood that not the slightest leakage was evident.

Where the pipelines are connected to valves and expansion sections, bolted flange joints are substituted for the cover straps. These are made from forged billets, machined to shape and secured to the pipes by welding. Alloy-steel bolts have been used in these joints, their high tensile strength enabling a smaller diameter of bolt to be used; in consequence, the bolt-circle diameter becomes correspondingly nearer to the pipe diameter and so reduces the eccentric loading on the welds.

The anchor blocks, which have been designed to hold the pipes securely under all conditions of load, are massively constructed, their weights ranging from 1,700 to 3,600 tons. Between the anchor blocks the pipes rest on curved metal saddles mounted on concrete piers spaced at 48 ft. centres. To provide for expansional and contractional movements, phosphor-bronze strips are attached to the saddles and permit an easy sliding movement. The total movement is accommodated by expansion joints of the stuffing-box type situated immediately below the three upper anchor blocks. These joints can be retreated 18 in. to allow access to the interior of the pipelines.

A site test was conducted in each section of the erected line by bolting blank flanges into the expansion joints and applying hydraulic pressure. Apart from insignificant weeps at a few of the rivets made on site and which were easily sealed by caulking, the pipelines stood up admirably to this test.

At the top of the pipeline there is a reinforced concrete valve house containing four 7 ft. diam. disc valves operated hydraulically through servo mechanism. These are primarily isolation valves and are normally only used for emptying the penstocks for inspection purposes but they are provided with trip gear which automatically comes into operation in the event of an overspeed caused by a ruptured pipe section or the breakage of a turbine runner. The servometer is operated by oil-air pressure generated jointly by an electrically driven two-stage air compressor and an oil pump, the resulting energy being stored in two cylinders at 300 lb. per sq. in. and automatically renewed as depleted. In addition to the emergency trip gear provided for the operation of these valves, they can also be opened and closed by two push-button controls situated in the valve house and remotely closed (not opened) by a single push button in the power house. Provision is also made for manual closing by means of a ram

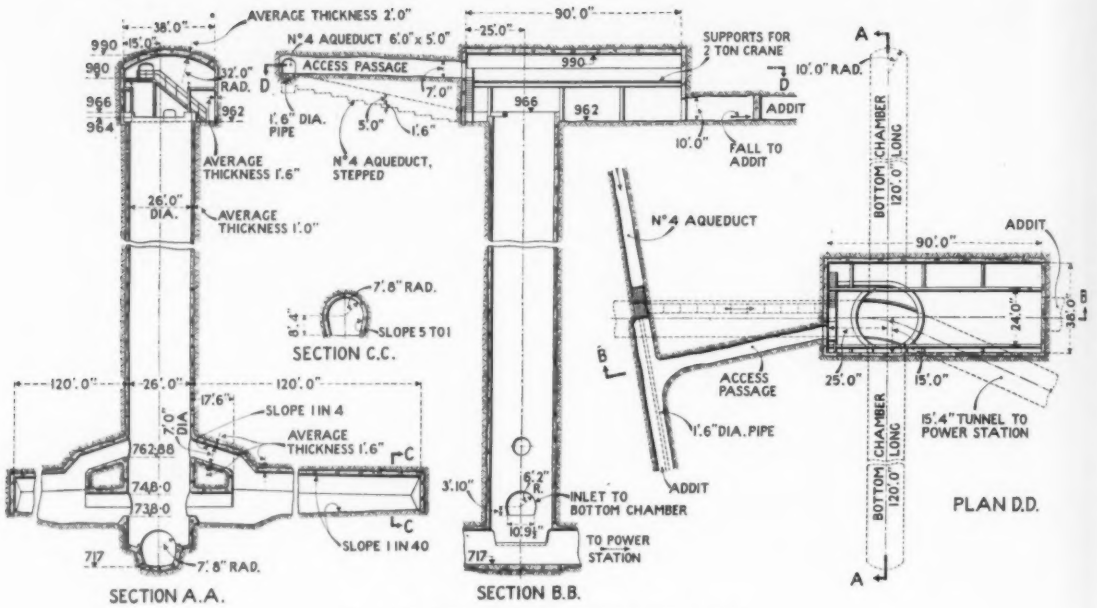

Fig. 15: General layout of the surge shaft

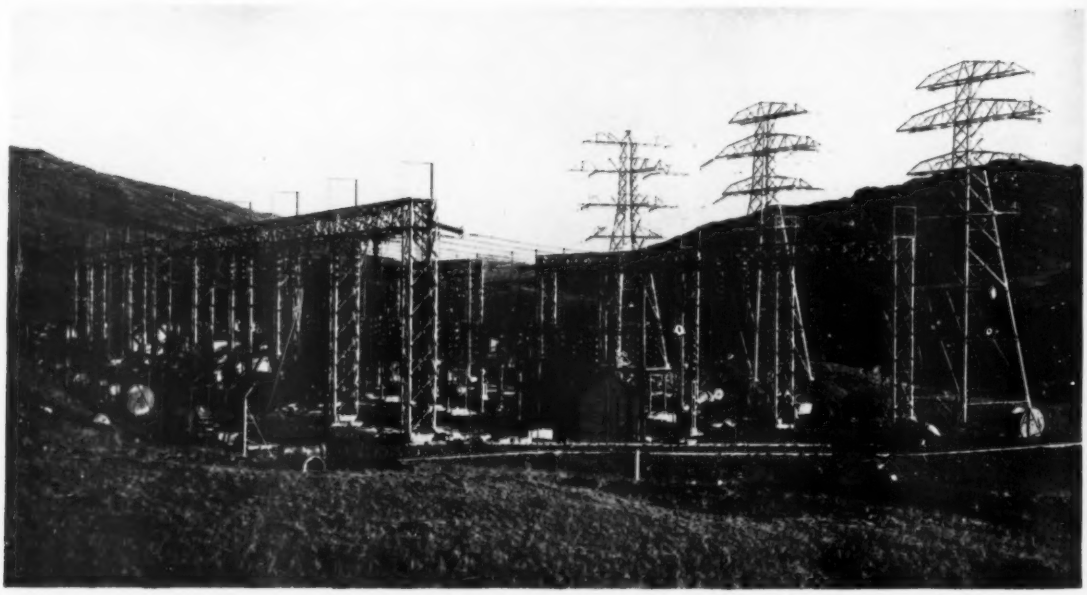

Fig. 16: View of 132,000 V switching station above Inveruglas feeding into B.E.A. network at Windyhill, Glasgow

pump. Complete sealing of the disc is effected by a rubber hose which passes around the periphery and can be inflated by a hand pump. For filling the main pipe again after it has been emptied for any reason, a 10 in. diam. bypass is provided, controlled by a manually operated sluice valve, and the disc valve is not opened until a pressure balance has been obtained. An anti-vacuum valve is also provided immediately below the disc valve to permit the escape of air when the pipeline is filled and to prevent the development of dangerous negative pressures should an overspeed occur. Also provided below each disc valve are a manhole and a drain pipe.

The valve house is equipped with a 25 ton capacity overhead travelling crane and there is an adequately sized bay at the end where dismantling and repairs can be effected. From this bay, access is given to an inclined railway for servicing the pipeline and transporting gear to and from the valve house.

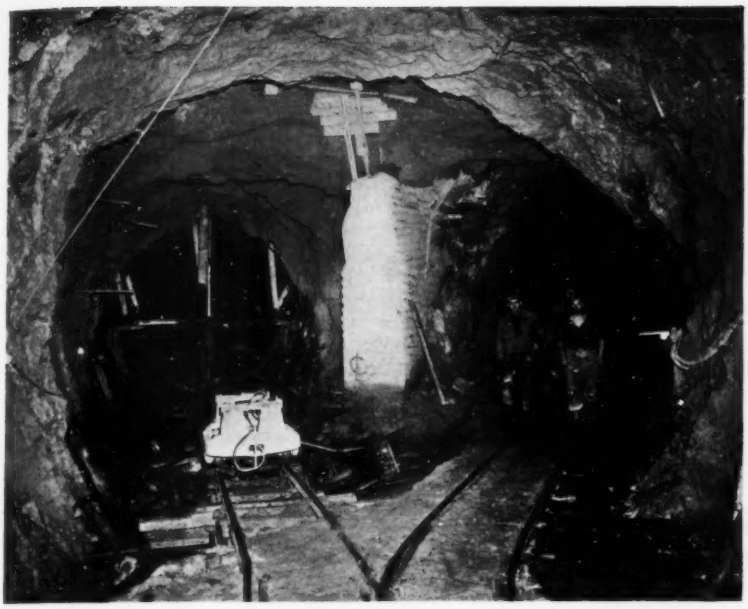

Fig. 17: Showing beginning of bifurcation of Sloy tunnel

Power station and machinery

The power station is a handsome edifice of concrete-filled girderwork which has been given a facing of precast slabs of Aberdeen granite, affording a finish that is natural and pleasing and harmonises well with the surroundings. As a further contribution to aesthetical susceptibilities the four pipelines have been painted with a subtle shade of green that tones in admirably with the general colouration of the hill sides.

To enable the machinery to be erected in good time the steel framework and crane-supporting columns of the power station were erected in skeleton form and roofed over with asphalting laid on hollow pre-cast slabs. The 120-ton overhead travelling crane was then installed and the erection work begun before the walls were completed. In addition to the main machinery hall, which is 190 ft. long by 52 ft. wide, the building contains a control room, switch room and spacious well-appointed administrative offices.

The generating plant consists of four vertical-shaft Francis turbines, spaced at 35 ft. centres, and each capable of developing 46,000 h.p. on the normal operation head of 860 ft. Each carries the rotor of a 32,500 kW generator and has a speed of 428 revs. per min. The operating floor has an elevation of 33 ft. O.D. and has an 18 ft. high loading and dismantling platform at one end. In the space under the platform duplicate 450 kW horizontal Pelton sets are installed to provide the current for local load and auxiliary purposes. These sets are operated from an 18 in. main connected with each of the 6 ft. 4 in. diam. pipelines, a hydraulically operated sluice valve being provided for each branch.

The spiral casings and draught tubes of the main turbines are completely embedded in mass concrete, in which, however, the necessary cavities have been left for pump wells, pipe ducts and inspection purposes. The pedestals carrying the alternators are 7 ft. in height and consist of welded steel frameworks enclosed in concrete. They are provided with openings for the governor arms and to give access to the turbine top. English Electric control valves of the cylindrical balanced type are installed below floor level and form the normal means of starting and stopping the turbines. These valves are situated at the entry of the spiral casings which are cast in steel in one piece and weigh 32 tons. As the pipe-lines are normally kept under pressure with all the upstream valves open, any set can be started up and synchronised within about four minutes.

To safeguard the pipelines against water-hammer effects in the event of a sudden line fault, relief valves are fitted in the spiral casings and disperse the pressure build-up direct into the tailrace. These valves are connected both mechanically and electrically with the mechanism operating the turbine gates in such a way that as the gates are closed the relief valves are opened and the pressure in the pipelines is kept within safe limits. Ultimately, when the regulating gates are closed the relief valves are shut off automatically at a predetermined rate.

The generators are totally enclosed and arranged for internal air cooling with air circulated through banks of water tubes.

The four main alternators generate at 11,000 V and the current is conveyed direct to step-up, water cooled, transformers, one to each machine, without intervening switchgear. Arranged on a platform on the anchor block at the back of the building the transformers step up the current to 132,000 V and at this tension it is taken to a main collecting and switch station situated about one mile up the glen. This distribution station is served by the road leading to the dam, and is a single bus bar installation with initially four feeder circuits and, eventually, six feeder circuits. It is intended that this station will also handle the current generated at the Shira and Allt-na-Lairige hydro-electric schemes being completed by the Board and these in turn will be interconnected with the Lawers and Tummel-Garry generating stations. In consequence the Sloy station will become a centre of control for a large section of the Board's undertaking and to this end the office accommodation is on rather more generous lines than would be necessary for the Sloy output alone.

Instrumentation

Mention has already been made of the water levels that are recorded on the upstream face of the dam and immediately downstream of the fine

screens, the differential recorded serving as an indication of when the screen needs to be cleaned. Both recordings are registered direct on mercury manometer gauges installed in a small housing at the bottom of the central buttress. In addition the reservoir level is transferred to both the intake gear house and the power station control room by means of electronic transmitter and repeater units. This apparatus was supplied by The British Pitometer Co. Ltd., in conjunction with Evershed & Vignoles Ltd., who provided the electronic equipment.

For the spillway, although there are no gauges to indicate the rate or duration of flood flow, an ingenious device has been installed in order to compute the total amount of spate over any specific period. This appliance incorporates twelve small-diameter orifices ranged at vertical intervals of 3 in. between the crest of the dam (935 O.D.) and the maximum estimated flood level (938 O.D.). As the water rises the orifices come successively into operation and discharge into a tank located in a well slightly below the roadway level. As will readily be understood the total quantity of water collected in the tank is directly proportional to the spillage over the crest and after an observation has been made the tank can be rapidly emptied by means of a drain cock.

In the surge shaft an indicator gauge and continuous recorder are operated by an air-bell system, the air pressure in the bell due to the head of water being transmitted to an indicating instrument and recorder by means of a length of $\frac{1}{8}$ in. bore copper tubing as shown in Fig. 9. By these means it is not only possible to have a continuous history of the water-level oscillations in the shaft, caused by the inertia effects on starting and stopping the turbines, but also to know exactly what losses of head are incurred at the different rates of flow. This equipment was made by The British Pitometer Co. Ltd.

In the valve house two Bourdon gauges are provided on each of the four pipelines, one immediately upstream and the other immediately downstream of the balanced disc valves. The function of these gauges is to ensure equal pressure on both sides of the main valves, by means of the by-pass, before they are opened.

Turbine instruments

Each turbine is provided with English Electric Bourdon gauges to register the pressure in ft. head and lb. per sq. in. immediately upstream of the cylindrical valve, in the spiral casing (i.e. downstream of the cylindrical valve) and finally in the draught tube—the last, of course, registering negative pressure. For measuring the flow to each turbine, flow meters operating on the Winter Kennedy method are fitted. These meters indicate and record the rate of flow and are provided with integrators. The meters, which are of the conventional type used in conjunction with venturi tubes are operated by the differential pressure across two tappings in the spiral casings, one tapping on the outer periphery and the second at a point towards the inside of the spiral casing and so positioned that suitable differential heads for operating the meter, are produced. In order to calibrate these meters accurately brine velocity tests will be conducted on two of the pressure pipelines. It is proposed to inject the brine into the pipelines a short distance downstream of the valve house and note the time interval which elapses before it passes a set of electrodes situated in their lower ends. As the volume of the pipeline is known the quantity of water flowing can be calculated from the time obtained in the test.

It is understood that these tests will be carried out by The British Pitometer Co. Ltd. This firm have also been responsible for supplying an interesting metering arrangement at the Allt Narne intake aqueduct on the Butteridge section to the east of the head of Loch Sloy. Here there are two recorders. The first is situated immediately downstream of the intake chamber where a flume has been constructed, the flow through which is registered on a disc recorder; there is also an indicator and integrator. The object of the second recorder is to measure the flow of flood water over the intake weir. By these measurements it is expected to obtain corroborative data that can be used to design intakes with more certainty in the Highlands generally. It is particularly sought to establish the relationship which exists between rainfall and run-off in this region so that the most economical size of aqeduct can be designed. At present the aqueducts are generally designed to cope with four times the average annual flow, and from the flow duration curves so far obtained it is estimated that over 95 per cent. of the available water will be directed into the reservoir.

Acknowledgements

In concluding this account of the Sloy scheme we gratefully acknowledge our indebtedness to Sir Edward MacColl, Deputy Chairman of the North of Scotland Hydro-Electric Board, for kindly permitting us to inspect the works and to publish this article. We also place on record our thanks to Messrs. James Williamson & Partners and to Messrs. Kennedy and Donkin, consulting engineers, respectively, for the civil engineers works and for the power plant and machinery, for their kind assistance in providing us with much of the necessary data.

The chief contractors taking part in the completion of the scheme were: Balfour, Beatty & Co. Ltd.—the dam at Sloy and certain connecting tunnels and aqueducts; Keir & Cawdor Limited—quarry work and conveying the aggregate to the dam site; Edmund Nuttall, Sons & Co. (London) Ltd.—the main tunnel, collecting tunnels and aqueducts; Sir William Arrol & Co. Ltd.—pipe lines, valve house, power station steelwork and 120 ton travelling crane; P. & W. McLellan, Limited—coarse screens for intake 13 ft. 6 in. dia. riveted pipe and tunnel lining; Glenfield & Kennedy Limited—valve and fine screens at dam, disc valves in valve house and tail race gates; English Electric Co. Ltd.—turbines, alternators, valves in power house and 11,000 v—132,000 v transformers; The Mirrlees Watson Co. Ltd.—cooling water pumps; Mechans Limited—draught-tubes bends; Crowley Russell & Co. Ltd.—camp and access roads and tail race bridge; A. M. Carmichael Limited—other access roads; Hugh Leggatt Limited—power house foundations and superstructures including the tail race and administrative block and the 132 kV substation.

Energy Resources of the World

Water power was specifically dealt with at the World Power Conference, recently held in London, under three headings. First, Resources and Location of Plant, on which thirteen papers were presented; second, Design of Water Power Stations, with five papers; and third, Aspects of Plant Design, with seven papers. A hydro-electric engineer of international experience reviews the general trend of developments.

CONSIDERING the contributions to the Hydro-Electric Section as a whole, four major characteristics may be noted:

(1) Great stress laid on underground station design and practice, particularly in Europe.
(2) A remarkable increase in the heads under which Francis and Kaplan turbines can operate.
(3) The high capacity of individual units and high individual power station capacities in North America.
(4) An almost complete absence of remarks regarding pumped-storage or hydraulic accumulator stations.

The stress laid by two Scandinavian papers on the design of, and operating experience gained in, underground power stations, coupled with the fact that such stations have been long running satisfactorily in Switzerland, show that the special design features associated with these schemes merit close investigation and analysis. One member in discussion advocated that a committee of the Conference be set up to collect and analyse the available data and obtain as much information as possible on the subject to assist designers of future underground stations.

Australia, Brazil, the Philippines and Great Britain are among the many nations which have designs well advanced for subterranean stations.

Most remarkable in recent years has been the advances made in the design of reaction turbines to operate under higher heads. When in 1930 a unit for 100 ft. head was developed it was considered remarkable; yet, 20 years later, a large unit exists which runs under 154 ft. head; another for 188 ft. head is in the design stage, and will shortly be manufactured, while research has shown that a design for 200 ft. head should present no difficulties. Francis turbines, as one paper shows, are now also capable of being designed for heads up to 1,650 ft., previously considered the exclusive domain of the impulse turbine. The contributions to the conference have also brought out the relative merits and demerits of the two types for "border-line" cases. One speaker even denied that the impulse turbine was superior when the water carried sand, his experience being that with proper materials the Francis turbine was preferable.

It was a pity that no reference was made to design limitations of generators. Francis turbines have a higher running speed, under like conditions of output and head, than impulse types, and a Kaplan runs faster than a Francis turbine; the runaway speed is also higher. Now a generator rotor is limited in diameter by the maximum permissible peripheral velocity which occurs at overspeed. The well-known design parameter for a generator is D^2l—for a given output the smaller D is made the greater is l (the core length) and the greater the cooling difficulties. It has actually been found in practice that for very large outputs the hydraulic turbine could be run at a higher speed than the generator designer is prepared to tolerate.

The United States communications show that with the large power networks that obtain there, large capacity individual stations are the rule rather than the exception. Also, as the total connected capacity is large, individual units can be made of considerable output without disturbing unduly the equilibrium of the system in the event of a breakdown. It will probably be a long time before any other nation is similarly placed, but it is notable that all the statistical data available, particularly from manufacturers, show a continuous upward trend in turbo-generator individual capacities throughout the world, and 60 MW units are commonplace. In this connection the French contribution urging a halt to this trend is particularly interesting.

At the Conference held in Berlin in 1930 great emphasis was laid on the value of the hydraulic accumulator station for meeting peak loads and improving the load factor of steam stations with which they were intended to operate. Except for certain references to large capacity pumps (40,000 and 60,000 h.p.) for such accumulator service, very few additional installations of this type would appear to have arisen since those early stations in Germany; even the pump capacities have not increased appreciably.

Finally, special attention must be called to the Swiss proposal that turbine performance figures should be based on model tests and not full scale results. It is well known that the measurement of large volumes of water is not easy and can be inaccurate and difficult for site reasons. Because of this there is a practice growing in America to accept model tests and waive site testing, particularly for Kaplan turbines; nevertheless, it does appear to be a retrograde step to urge a more general acceptance of model tests. Scientific site tests can afford much valuable information to the designer; the operator also has a more positive check on his machine than is provided by prototype tests duly "sealed" up. Again, the exact site conditions are rarely reproduced in the laboratory. Frequently the same casing and guide apparatus, and general set up are used for a number of different tests, the runner only being altered—not satisfactory conditions from the user's point of view. The generally accepted formula for "scale effect," while useful for the designer, is also empirical and still being subjected

to modification by its author. Therefore there seems to be insufficient data from which the definite efficiency of the full-scale machine can be assessed, and further careful site tests appear to be essential before this can be established.

PAPERS SUBMITTED

1.—Resources and Location of Power

Generation of Hydro-Electric Power in Canada, by Dr. Otto Holden (Assistant General Manager—Engineering, The Hydro-Electric Power Commission of Ontario). Referring to the changes in design practice that have occurred in Canada in the last 25 years, when the installed capacity rose from four million to 11 million h.p., the author points out specially that earth dams are now being increasingly used, thanks to recent advances in the knowledge of soil mechanics on the one hand and improved earth shifting equipment on the other. He also indicates that, as has long been the case in Europe, outdoor transformer and switching stations are generally coming into favour.

Local topographic conditions have resulted in a preponderance of reaction turbines. It is surprising to note that fixed blade propellor turbines still enjoy a wide popularity; their poor operating characteristics make them unpopular in Europe. Generator design appears to have followed European practice in adopting closed circuit ventilation and fabrication of parts.

Swedish Practice in Water-Power Development, by G. Westerberg (Chief Director, Civil Engineering Department, State Power Board), and Professor B. Hellstrom (Consulting Engineer). The now well known trend in Sweden towards underground power stations is here clearly set out and much valuable information is given of stations in service or under construction. Some brief notes on a new reinforced concrete buttress dam are also mentioned.

State of Hydro-Electric Power Development in the United States, by E. Robert De Luccia (Chief, Bureau of Power), and Frank Lloyd Weaver (Chief, Division of River Basins, U.S. Federal Power Commission). From the considerable amount of statistical information given the outstanding development in the United States lies in the size of the individual unit and capacity of individual stations culminating in the Grand Coulee project with 18 units of 130,000 kW each. The normal maximum heads under which reaction type machines are used is lower than in Europe, being about 900 ft. for Francis turbines and 100 ft. for Kaplans.

In an endeavour to reduce the initial cost of a project attention is being given to the outdoor type of station, but the underground station is still regarded as a novelty.

Roughly one quarter of the installed capacity and one quarter of the kilowatt hours generated in the country are stated to be produced by water power, showing that no special part of the load curve is met by hydro-electric stations.

The Production of Hydro-Electric Power and the Problems of Irrigation in Northern Italy, by Professor Marco Semenza (Consulting Engineer). The coordination between the water power development of the Alps and the irrigation requirements of the Po valley is fully described and details are given of some high level reservoirs which accumulate the summer flow for use in winter when little water is available in the Alps.

Les Grand Reservoirs et la Regularisation de la Production Electrique en Italia, by L. Selmo (Societa Idroelettrica Piemonte). In many respects this paper is a sequel to the previous one, since it deals with the design of large capacity reservoirs. The influence of thermal stations is indicated in a theoretical example.

Hydro-Electric Development in the Scottish Highlands, by Sir Edward MacColl (Deputy Chairman, North of Scotland Hydro-Electric Board). It is only over a period of seven years that the hydro-electric development of Scotland has been properly undertaken, but Sir Edward MacColl shows that already plans are well advanced for the installation of some three-quarter million kW of plant, including a Kaplan turbo-alternator to operate under the unusually high head of 188 ft.

There are two special characteristics of the Scottish Developments: one is the extensive tunnelling that allows the waters from one catchment area to be carried economically to an adjacent catchment that is limited in extent; the other feature is the intention to operate stations as groups, remote controlled from a central point.

Repartition des Nouvelles Puissances Thermiques et Hydrauliques Installees en Algerie, by P. Crosnier (Directeur Général Adjoint d'Electricité et Gaz d'Algérie).—A general comparison is given between hydro-electric and thermal power generation. The author also differentiates between " run of river " and firm capacity hydro-electric stations. While the information applies entirely to Algeria, the methods used are universally applicable, and the paper is a useful contribution to power production economics.

2.—Design of Power Stations

Norwegian Hydro-Electric Power Stations built into Rock, by Ragnar Heggstad (Chief Engineer of the Board of Industrial Protection). For thirty years Norway has had underground stations in service. Although only five have been built during that period, a further fifteen such stations are now under construction, and the ultimate total capacity will exceed 1½ million kW. Head and output of these stations vary widely. The author provided a great deal of civil engineering design information that would assist the planning of an underground station.

The Design and Operation of Powerhouse and Equipment, by E. B. Strowger (Hydraulic Engineer, Buffalo Niagara Electric Corporation). From the statements made it would appear that European manufacturers have little to learn from designers across the Atlantic.

Considerations Generales sur la Taille des Equipements Hydro-Electriques, by M. Rousselier (Chef du Service des Projects Hydro-électriques, Electricité de France). The urge towards larger generating stations and larger individual generating units brings out special design and, more particularly, manufacturing problems. M. Rousselier sets out to show what these are and to indicate that, for the time being, he believes that further striving after greater size might prove uneconomic.

The complexity of the problem, due to the large number of independent variables is admitted, but a simplified solution based on dimensional analysis is

attempted. Dams and pipe lines are two extra-powerhouse items of special interest. The latter cannot be increased indefinitely along classical lines without the foundation costs rising steeply according to an exponential law. New designs are, however, being developed in France, Italy and Switzerland, which are anticipated to show economies in construction when the dam height exceeds about 600 feet. The limit set to pipe line size is the ability to weld the seams in the shops and on site due to the plate thickness increasing with the diameter. The use of the so-called "auto-frettage" or pre-stressed wire wound design of pipe now becoming widely employed in France, is suggested for large capacity high head pipes.

When considering the powerhouse equipment the author points out that after a certain limit, often dependent on local site conditions, it might not be economical to reduce the numbers of units further, as the actual weight of the material might be higher and the overall cost greater. In any case, transport and manufacturing capacity will also set a limit to the economic size. Thus it is suggested that 100,000 kVA is normally the convenient and economic size limit, though for Kaplans the upper limit might be 60,000 kVA because of dimensional limitations.

The Suitable Layout of Low-Head Hydro-Electric Plants built next to weirs, by Ing. Jaroslav Cabelka (Scientific Officer of the T.G. Masaryk National Hydrological Institute, Prague). In an attempt to achieve cheapness in initial cost low head stations, forming a continuation of a weir, were built in the past without due regard to the very heavy losses that arose with incorrect approaches. The author finds that losses up to 10 per cent. per annum can be encountered, and his experiments show that they can be reduced or eliminated by more careful design of the approaches to the station. The modifications are relatively small and the cost fully repaid.

Available Power and Delivery of Water to the Powerhouse, by William F. Uhl, Byron O. McCoy, Charles T. Main (Boston), and William P. Creager (Consulting Engineer, Buffalo). After pointing out that many of the largest North American schemes are those designed for multi-purpose operation, and that the power available is, therefore, partly dependent on the requirements of the other users, increased output is stated to be obtained mainly by improved flow forecasting methods.

3.—Aspects of Plant Design

Recent Achievements in the Design of Prime Movers for Hydro-Electric Power Stations, by Arne Fismen (Chief Engineer, Als Kvaerner Brug). Somewhat surprisingly this paper, which is devoted to the work done by the author's company on turbine design, sets the upper limit of head for the Kaplan at around 100 ft., although it goes on to say that Francis machines have to be designed for 1,500 ft. and could even be used under 1,600 ft. in certain circumstances. It is conceded that normally for high heads an impulse wheel would be used with multi-jet arrangement, and there appears to be no upper limit.

Le Replacement des Essais de Reception a Pied D'Oeuvre Dans Les Centrales Hydrauliques Par Des Essais Sur Modele Reduit, by E. Seitz and C. Keller (Escher Wyss, S.A., Zurich). It has long been appreciated that the accurate measurement of large volumes of water is a matter of considerable difficulty. On the other hand, small quantities of water, such as are in question in the laboratory, are capable of very accurate gauging. Ready means also exist for adjusting model test results to the full scale unit. The authors, therefore, suggest that it appears desirable to accept model test results, suitably adjusted, for a full-scale design. They also point out that much valuable information can be obtained about a machine by testing it in an air stream; this method of testing yields results which, when properly interpreted, are not economically obtainable in any other way.

Kaplan Turbine Blading, by Dr. M. Nechleba. This paper is a valuable addition to the comparatively scarce published data on Kaplan turbine design. It is alleged that blades of identical shape, differing only in length and number, can be used for various specific speeds and heads. Satisfactory tests have been made using four, five and eight blades; they will shortly be extended to cover other numbers of blades. Based on the theory used in designing the models and developed fully in the paper, a Kaplan for the exceptionally high head of 200 ft. has been developed.

La Construction en Italie de Turbines Hydrauliques de Grande Puissance et de Pompes pour Installations d'Accumulation, by Dr. Ing. Guido Ucelli (Director General, Société Constructions Mechaniques Riva-Milan). Within Italy turbine unit capacities have increased from 3,000 h.p. at the turn of the century, to 100,000 h.p. to-day. Among many notable installations is a single nozzle impulse turbine developing 60,000 h.p. The division of heads into turbine types is indicated, and special mention made of the relative merits of Francis and Impulse turbines where the types overlap.

A valuable contribution lies in the plea for some degree of standardization throughout the world of the manner in which guarantees are given, and methods of carrying out acceptance tests.

Some details are also given of large capacity pumps for use in hydraulic accumulator stations, including a pump of 61,000 h.p. operating against a manometric head ranging from 790 to 940 ft., and another of 37,000 h.p. working against a manometric head of 2,000 ft.

Quelques Developpements dans le Domaine des Centrales Hydrauliques Specialement en ce qui Concerne les Conduites Forcées et Pompes d'Accumulation, by J. Gastpar and R. Thomann (Directeurs, Sulzer Frères SA., Winterthur). It is shown that the development of special steels and improved manufacturing methods have resulted in an appreciable reduction in the material used and cost of penstocks for hydro-electric stations.

Stone and Gravel Separator for Water Power Conduit, by Hans Sorbye (formerly Chief Mechanical Engineer, Norges Vassdrags-og Elektrisitetsvesen). Detritus has always been a source of worry to the hydraulic power station operator. In some cases he has behind his machines an unlined tunnel, in others a river that carries considerable quantities of sand: sometimes continuously, sometimes only in times of flood. In all cases the presence of this foreign matter can be a serious inconvenience and even a danger.

In this paper is described a device for assisting the removal of sand and stones which has been for some

time in operation in Norway, and has now proved its worth. The normal velocity of the water is decreased by an enlargement in the pipe which permits the detritus carried to drop to the bottom. Suitable baffles are inserted to give the water the direction of flow required to do this. The matter so trapped is stored until the turbine is shut down, then the sand and gravel are emptied through a man-hole.

The system was tried on a full-scale plant without previous tests; it proved so effective that other pipe lines at the same station are to be similarly fitted. A similar device has been worked out for a tunnel. Here the velocity is too low already, so the active part of the separator is actually less in area than the tunnel, and the material is disposed of by centrifugal force. Emptying in this case is through a pipe and valve leading into a chamber cut out of the rock below the separator. By this means the necessity for shutting down the tunnel is avoided.

Progress in the Design of Chamber Surge Tanks, by Ir. R. M. Sedijatmo (Designing Engineer, Department of Power, United States of Indonesia). The necessity for standard types of surge tank is described. Then a brief description of the author's design for a tank, intended to combine the advantages of others, is given and an example worked out.

The scheme advocated is an adaptation of the Schuller system, combining the two chambers of a two-chamber design into one; but instead of the water from the riser flowing over a spillway into a discharge duct, the pipe and chamber are connected through a weighted ball valve to each other. The ball valve operates when a certain load obtains in the riser.

NEW SOURCES OF POWER

It was perhaps a little disappointing that the papers dealing with new sources of power were only four in number—they referred to wind power, the utilisation of natural steam in the North of Italy, the difference in temperature between the bottom and the surface of the sea in tropical regions, and the use of the heat pump. Atomic energy was discussed separately.

In the first contribution by Messrs. Haldane and Golding (Great Britain), it was shown that a very careful survey has taken place into the possibilities of utilising wind power in Great Britain, and two experimental 100 kW aero-generators are in the course of construction, one by the North of Scotland Hydro-Electric Board to be installed at Costa Head in the Orkneys, and the other by the B.E.A. for a site at Hayle in Cornwall.

The coasts of Britain have an average annual wind force of approximately 15 miles an hour, which is higher than that of many other parts of Europe. The extensive British grid system enables the intermittent energy available from the wind to be usefully employed, and from an economical standpoint, there is every reason to believe that wind generators might make a useful contribution to the power resources of this country, if sufficient generators were installed. Development is likely to take the form of employing a large number of small aero-generators rather than a smaller number of large ones, and it is expected that the final stage of the present investigation will result in the building of a full-scale set of between 1,000 and 2,000 kW capacity.

The 100 kW experimental generator to be established in the Orkneys will produce about half a million kW a year. The type of machine to be used at Hayle employs a three-bladed propeller having a tip circle of 79 feet diameter with its centre line 130 feet above the ground. The blades are hollow, and the centrifugal action due to revolution causes air to be expelled, thus creating a suction through the hollow hub and down the supporting column. This suction acts on a wind turbine at the foot, coupled to an a.c. generator. The blades are of the variable pitch type, and a small vane at the tail end actuates the feathering blades in such a manner as to provide a reasonably constant speed of rotation over a wide range of wind speeds. This device, coupled with the regulating arrangement on the wind turbine, enables the generator to operate at synchronous speed and to be coupled to the grid network.

The paper from Italy discussed the use of natural steam existing in Tuscany; this had been harnessed to provide power, and in view of the nature of the steam it is regarded (in the words of Mr. C. W. Marshall, Deputy Chief Engineer, Research, B.E.A.) as "a unique and epic achievement in engineering history." The steam found in the *soffiones* is wet saturated with a dryness fraction of 0.8 to 0.9, at a pressure of 15 to 18 atmospheres. It is contaminated with a number of gases including carbon dioxide, hydrogen sulphide, hydrogen, methane and nitrogen, and has a temperature range in various *soffiones* from 285 deg. to 420 deg. F. It is utilised for power generation in three ways; first in a back pressure turbine exhausting into a chemical plant, secondly in condensing turbines using heat exchangers so that in the actual turbine uncontaminated dry steam is used, and finally in condensing turbines directly utilising the steam-gas mixture. A considerable amount of electrical energy is produced by these various plans which are being extended.

Perhaps the most interesting project was that described in a paper by MM. Beau and Nizery, in which they gave particulars of a plant to be installed at Abidjan on the Ivory Coast of West Africa, to generate power by utilising the difference in temperature between the surface and bottom of the ocean. It was shown that the vertical temperature gradient in the seas in that region exceeded 68 deg. F. between the surface and a depth of 1,640 feet. Warm water from the surface is pumped into the turbine and condenser assembly, a part of which is maintained at a high degree of vacuum. This causes immediate evaporation of the warm water, and the vapour passes through the blades of a turbine and thence to a condenser. Here cold water from the bottom of the sea condenses the vapour, causing a vacuum which creates the suction to drive the turbine. The air extraction plant will absorb one-fifteenth of the total power; and for a 5,800 kW turbine very large dimensions are necessary — the diameter of the turbine wheel will be 26 feet, running at 600 r.p.m. Reinforced concrete will be used for the enclosures of the turbine, with a lining to ensure a vacuum. The water inlet will be $2\frac{1}{2}$ miles from the shore, and will consist of a steel pipe and a semi-rigid portion using rubber connectors. Two generators, each of 3.5 MW capacity, will be installed at Abidjan, and engineers will watch this development with great interest, since it opens up many new possibilities.

The final paper in this section was from the United States and it dealt with the possibilities of the heat pump which produces energy in the form of relatively low temperature heat by a "reverse refrigerating" action. Over 500 installations exist in the United States, ranging in capacity from 3 kW to 460 kW; air, water and earth are used as the heat sources. British engineers have also contributed a great deal to heat pump research.

ATOMIC ENERGY

All the speakers in the section of the World Power Conference devoted to the possibilities of using atomic energy for power generation warned against undue optimism, particularly in regard to the time factor. They stated that in no case was it likely to be less than ten years, and in many cases it might be as much as 25 years before the first economically workable atomic pile was in commercial operation. It was emphasized that as a potential source of power atomic energy should not be allowed to detract from the development of existing power resources.

A survey of the problems was given by Mr. Norman Elce, director and chief mechanical engineer, Metropolitan Vickers Electrical Company, who said that the initial power plants were likely to be dual circuit systems employing a primary circuit which transferred heat from the reactor to the motive fluid of a heat-engine circuit. It was probable that helium was the only known medium for the primary circuit, operating at a pressure of several hundred lbs. per square inch in a hermetically sealed arrangement of piping.

Some of the enormous problems which yet had to be solved related to the means of control. Any form of forced circulation for the primary circuit would mean the presence of glands through which radio-active materials might escape, thus causing danger to operators and destruction to the plant material. If a purely convective system were used control would be even more difficult. There was also much investigation to be done on the effects of radioactive materials on the various parts of the plant itself; on the disposal of radioactive waste products; on remote control problems, and on means for protecting the plant in the event of a serious technical fault developing.

On the optimistic side there was considerable discussion on "breeder reactors," and although views were not unanimous it was thought that once a sufficient supply of the primary atomic fuel (uranium 235) had been secured it might be possible to produce secondary materials, which were equally suitable for use in atomic piles, by breeding. Some scientists were of the opinion that breeding would increase the supply of available atomic fuel by as much as 5 per cent., so that a stage would come when no further raw fuel would be needed.

Many speakers, including Sir John Cockcroft, director of the British Atomic Energy Research Establishment at Harwell, and Mr. Ward F. Davidson of the Consolidated Edison Company of New York, were asked if they could give any indication of the probable cost of atomic energy once a power station had been constructed. No one would commit himself in this direction; the speakers would only go so far as to mention the factors which influenced the cost. Mr. Davidson said that it may be taken as certain that the costs would be significantly higher than for coal burning stations and for most hydro-electric plants. Nevertheless, nuclear power plants might be built as part of a multi-purpose development, with other outputs for their activities such as the production of radioisotopes. Until many years of successful operation have proved their reliability no prudent engineer would place a large nuclear power station in the heart of a city, or in densely populated or industrially important areas. The ever-present chance, however small, that something might go wrong and release large amounts of intensive radioactive material would dictate sites in areas where a failure would be less disastrous. This factor might add materially to the costs because of the transmission networks which would thus become necessary. Nevertheless, on the credit side the saving in transport costs of fuel, which would be negligible compared with those for coal, was a factor which had to be considered.

ANTI-CORROSIVE TREATMENT FOR PIPELINES

A party of engineers recently attended a demonstration at the British Electricity Authority's Carrington Power Station, Manchester, to inspect a mobile unit manufactured and operated by Schori Metallising Process Ltd. in process of protecting circulating water pipes against corrosion. The pipes

Six feet diameter pipes sprayed with zinc for protection—Mont Sherraud Hydro-Electric Scheme, Switzerland. Pipe line on right has yet to be treated

were being flame sprayed with zinc powder, this deposition being followed by painting. As the work on this site will continue for several months, a temporary building to provide the necessary cover and screening arrangements has been erected.

The majority of the pipes weigh 5½ tons each and are made of ⅝ in. mild steel and measure 6 ft. 6 in. dia. by 20 ft. long. They are complete with stiffeners and supports. A number of puddle flanges and expansion joints and bends are also to be treated. The pipes are brought alongside the building on rails, lifted by crane on to bogies on a jubilee track, which passes through the building. The pipes are shot-blasted then zinc sprayed and subsequently painted, finally they are lifted by gantry back on to the rails for removal to the assembly site.

The interior and exterior surfaces of the pipe work are first blasted with grit for the removal of all rust and scale, the resulting toughened and clean surface forming an ideal base for the zinc coating. The normal speed of blasting is 90 sq. ft. per hour. A coating of pure zinc, 0.006 in. thick, is then applied, spraying at a speed of approximately 140 sq. ft. per hour with the Schorl Model 50 pistol. One coat of zinc Chromate Primer is next applied, and then two coats of bitumastic paint.

After the pipes have been welded together in position, all the welded joints are touched up in situ, special precautions being taken to avoid damage to the coating in other parts of the pipeline.

Compressed air for blasting and spraying is supplied by three Broom-Wade Compressors, each machine having a capacity of 167 cu. ft. of free air per minute at a pressure of 100 lb. per sq. in. These compressors are driven by Lister diesel engines and are linked together and controlled by one governor. The air is pumped into two receivers, from which the air is passed through a water cooler and two coke filters before it goes to the spraying pistols.

We understand this process has recently been used to treat the 6 ft. pipelines in the Mont Sherraud hydro-electric scheme in Switzerland, and that it will be used for the pipelines on the Fasnakyle hydro-electric scheme in Scotland.

From our Parliamentary Correspondent

The hydro-electric schemes for North Wales and Scotland figured largely during the House of Commons debate on the report of the British Electricity Authority.

Mr. Emrys Roberts (Merioneth) said the schemes in North Wales provoked considerable controversy. Surely the right attitude to adopt towards them was neither unqualified acceptance nor complete rejection. Some parts of the schemes were completely unacceptable, other parts were acceptable. The main consideration was that the voice which mattered when they considered these schemes was the voice of the people of Wales. It was their land and their heritage. At present there were far too many claims of a technical or departmental character upon the land. He believed the people of North Wales wanted to develop all the hydro-electricity possible, and that with sympathy, skill and comprehensive planning it could be done in a manner that would not spoil the wild grandeur of the Welsh mountains and valleys.

Lord Malcolm Douglas Hamilton (Conservative, Inverness) mentioned a case in the Kilmorack area, a township consisting of 80 crofters. The deputy chairman of the North of Scotland Hydro-Electric Board, Sir Edward MacColl, had pointed out that to cover this area would cost £18,500, with a running cost of £3,700, whereas the amount that would be received back from the area would be at the most only £800. That was very unprofitable. In consequence, Sir Edward MacColl had asked consumers to contribute £10 a head in capital charge and to guarantee £10 a year. No one objected to paying £10 a year. A crofter would certainly use that amount of electricity, but it was a lot for a crofter to pay £10 capital down, which after all would not make very much difference to the loss the Board incurred. That was not an isolated case: it was symptomatic of what was happening in one or two other places. The warning obviously was that there would be a tendency to put increased capital charges on local areas. He would like to know if the Secretary of State had any statement to make on the matter.

Recently the President of the Board of Trade said that it might be difficult to persuade private enterprise to come up to Corpach in the Fort William area; but if they got sufficient inducement it would be easy enough. One of the biggest inducements for private enterprise would be cheap power. The tendency was for a tremendous increase in the cost of construction of the hydro schemes, which influenced the cost of power. Mr. Tom Johnston hoped that electrical, chemical and metallurgical industries might be established in the Highlands. Lately there had been uneasiness because of these increased costs, and they had tempered the high hopes once held. The tendency would be for the rural areas and industry in Scotland to be neglected and more power would tend to go into the grid. It was true that a profit was shown this year by the Hydro-Electric Board, but no entry could be found in the accounts for depreciation or amortization. They had great confidence in the Board as at present constituted, but Parliament gave its charter to the Board, and if the Board could not provide for developments in the Highlands then Parliament must take action.

Mrs. Eirene White (Labour, E. Flint) emphasized that the seven or eight schemes for hydro-electric generation in North Wales were not mutually dependent, but could be developed separately. She urged that the authority should not embark upon the most controversial of these schemes at the outset, but should take certain of those which were not controversial, such as the Rheidol scheme for the Aberystwyth district. They would then see just what was meant by the construction involved, and the people of Wales might have a more adequate opportunity of judging whether they wished to have this

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Industrial Future of Scottish Highlands

A PROGRAMME of Highland development, published by the Scottish Office as a White Paper, says the most important manufacturing industry in the Highlands is the production of aluminium by electrolysis, using hydro-electric power generated by the British Aluminium Company. It is the only source of aluminium in this country. The average annual output of electricity from the North of Scotland Hydro-Electric Board's water power schemes, according to the latest estimates, will amount to some 350 million units by 1953; the potential output is much greater, and if all the schemes included in the crofting counties section of the Board's development plan are brought into operation they may produce as much as 4,650 million units a year, which is the electrical equivalent of 2.9 million tons of coal.

The White Paper also states that during the four years 1950-53 the North of Scotland Hydro-Electric Board propose to spend £20 millions on constructional schemes and £2 millions on distribution schemes in the seven crofting counties, and it is expected that by the winter of 1952-53 sufficient new plant will have been installed to increase the capacity available for winter peak loads by 161,800 kilowatts, as follows:—

At the same time, in the whole of the Board's area it is expected that 390,000 kilowatts of new plant will have been installed.

The Board's first statutory duty is to supply ordinary consumers — among them industrial and commercial users—in the North of Scotland, including those in the remote and isolated parts of the Highlands. Another 10,000-15,000 kilowatts will probably be available by the coming winter for the use of new industries in the Highlands and to meet growth of load there.

The water power resources which are being developed by the Board will ultimately produce much more electricity than is required to meet the foreseeable needs of the Highlands and the surplus energy will be sold to the British Electricity Authority at a price which is expected to provide a profit.

The Cooper Committee on Hydro-Electric Development, whose report formed the basis of the Hydro-Electric Development (Scotland) Act, 1943, envisaged the setting up in the Highlands of industries requiring large supplies of electric power, such as the electro-chemical and electro-metallurgical industries. Rising costs of construction and of heavy plant have greatly increased the capital expenditure of the North of Scotland Hydro-Electric Board, and the price the Board will be obliged to charge for power is a good deal higher than was expected when the scheme was first launched. Costs of power produced by thermal methods have also risen, however, and it is estimated that the cost of power from the North of Scotland Board will be cheaper than power produced by any new thermal station.

The North of Scotland Hydro-Electric Board and the Scottish Council (Development and Industry) are in touch with a number of firms who require large quantities of electric power and who might be interested in establishing factories in the Highlands.

		1948/49	1949/50	1950/51	1951/52	1952/53
		kW	kW	kW	kW	kW
New capacity installed	Argyll	—	—	6,000	2,000	40,000
	Inverness	600	—	22,000	45,600	20,000
	Ross and Cromarty	500	500	24,000	600	—
Total additional capacity available		1,100	1,600	53,600	101,800	161,800

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kind of development in the Snowdon area.

Lady Megan Lloyd George (Liberal, Anglesey) said the only question in dispute was whether the British Electricity Authority proposals were the most practical and the most economical, or whether more effective proposals could be made which would be far less destructive of the amenities of the area. It was proposed that there should be ten power stations in the National Park of North Wales, four of them on Snowdon itself. These buildings would be some 100 ft. long and 70 ft. high, and one could not hide a power station on a hill. These plans had been drawn up by engineers, but it also seemed that they had been drawn up by people with an unerring and piratical eye for beauty because they had hardly missed one of the really famous beauty spots in that part of the world.

Mr. Robens (Parliamentary Secretary, Ministry of Fuel and Power), replying, said when the North Wales hydro scheme was prepared it would have to be submitted to the Minister for his approval. In any case, a Bill must come before Parliament so there would be plenty of opportunity to deal with all the matters raised. He assured Lady Megan Lloyd George there was a good deal of sympathy with maintaining the good and beautiful conditions in Snowdonia.

Civil Engineering Maintenance

By JOHN WARNOCK, M.C., A.M.Inst.C.E., M.I.Struct.E., British Electricity Authority. An account of maintenance work in connection with concrete structures and steel work.

Un article sur les problèmes d'érosion du sol au voisinage des barrages et des canaux d'amenée et sur méthodes employées pour en combattre le danger. L'auteur traite aussi de l'entretien des tunnels et des constructions métalliques employées dans les projets hydro-électriques et de l'importance d'une surface très finie sur les travaux en béton.

Una memoria versando sobre el problema relacionado con la erosión de tierras cerca de presas, corrientes de agua y canales de esclusa y sobre los métodos empleados para contrarrestar este peligro. El autor también hace una relación detallada de los trabajos de mantenimiento de túneles y de obra de acero empleados en proyectos de ingeniería hidro-eléctrica y hace referencia a la importancia que tiene un acabado satisfactorio de las superficies de las construcciones de hormigón relacionadas con estos proyectos.

THE useful life of the major part of the structures and plant associated with a hydro-electric power project is of unknown length, though it is clear that the actual life which may be expected depends, to a great extent, on the exercise of proper maintenance on the various types of structure and plant installed in such a scheme.

The maintenance of civil engineering works may be considered first in relation to an upland cut-off dam built across a stream. It generally forms the first item in the hydraulic chain that leads to a power plant. This dam, if well constructed, should require little maintenance repair for many years. The metal work associated with gates, valves, screens and fencing, even if specially treated in manufacture, will, in course of years, require attention, and this will be mentioned later as a whole, together with other metal work.

In any rapidly-flowing upland stream situated in moraine or other formations of a similar character, a continual movement downstream of gravel and sand is taking place and where a dam is erected over a stream, this forms an obstruction to flow and a gradual accumulation of gravel and sand will form behind the dam. It is necessary that an ample size of sluice gate should be provided in the dam wall so that the accumulated material behind the dam can be rapidly scoured away downstream when flood waters are running and the sluice gate can be opened up for a time.

Leets or Flumes

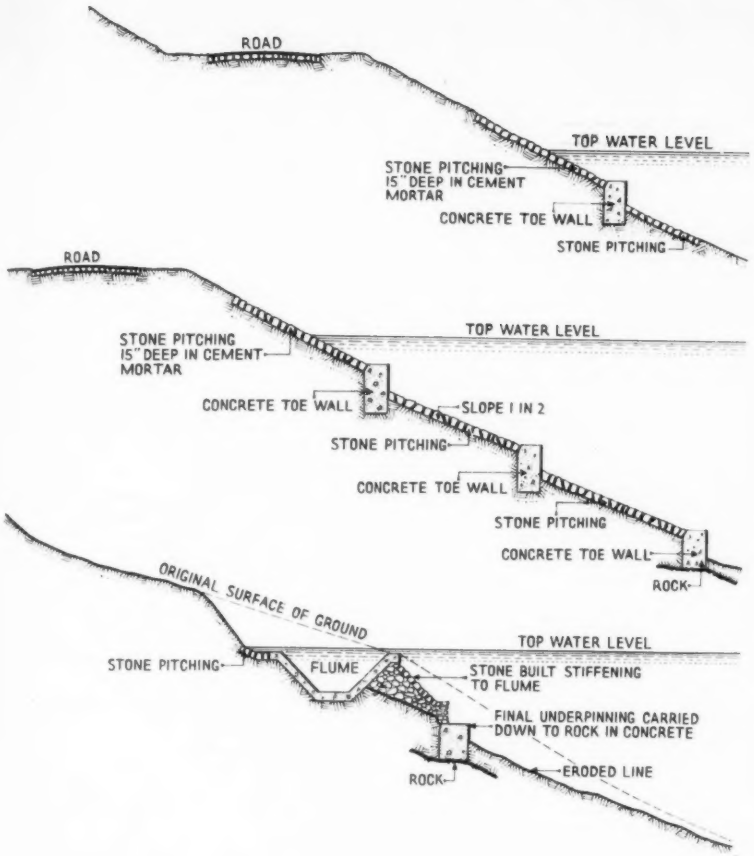
For economy in original construction costs, flumes or leets may be left unlined in suitable ground, but it is more usual and much more efficient to protect them with concrete. Generally the sides are sloped at 45°, the cross section being so proportioned that the sides and floor form tangents to a semicircle, the size of which is chosen to suit the flow required. Stone pitching has also been used occasionally for lining leets, but concrete is preferable and provides smoother surfaces. If not lined at the outset, the leet will tend to an increase in width through erosion and this will be accompanied by a gradual drop in the efficiency of discharge. Normally, the concrete lining in a medium size of leet averages 5 or 6 in. in thickness. In good ground steel reinforcement is not necessary and a durable job is secured by pouring ordinary concrete behind steel or timber shuttering and will amply repay the expense, as it will be more satisfactory in operation and will require less maintenance than an unlined channel. A well constructed leet should preferably have no straight longitudinal joints in its structure and the floor and sides should be cast as one complete slab. The slabs should be of suitable length and spaced at intervals, with intermediate sections built in later, to minimise shrinkage effects; with this type of construction the leet should remain in satisfactory condition for a great number of years.

The principal maintenance items on indifferently constructed leets are associated with unnecessary joints, i.e. longitudinal joints between the floor and side slabs, particularly when the sides have been constructed without the correct amount of slope. In regions subject to severe frost the fine surface finish of the leet during the course of years may tend to disintegrate and roughen and the effective discharge capacity of the leet will be reduced by the additional friction. In such regions, therefore, it is a wise precaution to increase the cross sectional area slightly to compensate this ultimate increase in friction.

On high exposed areas leets are liable to become completely blocked with snow. When snow is anticipated the water flow should be cut off if possible, otherwise an overflow may occur with perhaps severe damage to the embankment on the low level side of the leet.

Tunnels—Unlined and Lined

In suitable rock formations and where the walls are not subject to water pressure, tunnels need not be lined. Improved discharge will, however, be obtained if the waterway is lined with concrete, and for pressure tunnels it is usual for the tunnel to be completely lined. It is an advantage to give the lining a finish of bituminous paint which not only protects the concrete but also improves the discharge coefficient.



Maintenance of a tunnel is a lesser problem than normally experienced in open leets, and if well constructed to begin with a tunnel lining will give many years of service without much maintenance repair being required. In the case of waters carrying a heavy peat content, a coating of peat will adhere to the wetted surfaces in the course of years. This accumulation will cause a certain loss of sectional area, and there will also be an increased frictional resistance, with a consequent reduction of the operating head. The only means readily available of controlling the deposition of peat on the surfaces is to dry out the tunnel under suitable conditions in summer weather by inducing a good ventilating air flow. After the peat lining has dried out, it should part from the concrete surface and finally break away, on the water flow being resumed. When the thickness of peat lining has increased to, say, $\frac{3}{8}$ in., the effective drying out of the tunnel becomes difficult and the peat does not peel off easily unless it is dry. Removing the peat by a high-pressure water spray would then appear to be the only remedy, but this will be a lengthy and difficult operation in a long tunnel.

Main and Subsidiary Dams

To indicate the probable loss of effective head caused by peat formation, the original loss in frictional head in an actual concrete lined tunnel and pipe line was found to have increased by over 50 per cent. The resulting loss of effective operating head thus becomes of economic importance.

A well-constructed dam will require little maintenance work for many years. In the case of a solid concrete gravity dam, constructed in large block sections, there may be a tendency for a free lime deposit to be exuded at the construction joints in the course of time. The chemical reaction which causes the leaching of the lime from the cement may cause fairly extensive surface disfigurement. This loss of lime is difficult to prevent and in certain instances, a concrete mortar gunite finish has been applied on the water faces to prevent leakage and as a means of protection. This finish is keyed to the concrete surface by a reinforcing mesh of light steel, fixed off surface on the wall faces.

In those places where public amenities, such as roads, are situated in close proximity to a reservoir, the effects of surface soil erosion caused by the combined action of wind and wave along the edges of reservoirs may reach considerable proportions. Unless promptly attended to such inroads of erosion may entail considerable repair work. Wave action on moraine formations is particularly noticeable and has a very damaging effect on ground slopes. The silty material is leached out of the ground mass which is thus undermined to such an extent that a serious collapse may occur in a comparatively short space of time. If, of course, this erosion occurs away from public utilities, such as roads, it can probably be allowed to take its course without much hurt being done but immediate remedial measures are necessary when it is a matter of protecting expensive roadways or other public works.

In considering repair measures, it is found that if good stone is procurable locally, it will generally prove the most satisfactory material to use as a protective pitching for exposed slopes. The principal alternative is a concrete slab, but in general experience a stone pitched slope has a flexibility that renders it more satisfactory in use.

Where the undercutting of a bank has caused danger to a utility, a substantial and deeply set toe wall should be constructed down to a rock formation if possible—either in concrete or in stonework built in cement mortar. The eroded surfaces of the bank above the toe wall will require to be dressed off to an even incline which, in practice, should be graded to a slope of 1 in 2 to receive the protective stone apron. The pitching, to assure stability against wave action, should be fully 12 in. deep but should preferably be deeper with the stones laid on edge, normal to the slope, and securely built in cement mortar.

Some distinction can be drawn here between conditions which prevail on reservoirs lying at a high elevation and those at low levels. In the former case the weather conditions will at times be severe, and it is essential for stability that all stone pitching should be built in cement mortar, whereas at low levels where the wave action may be expected to be less violent, stone pitching without mortar may suffice.

Conditions may occur where the erosion of a long steep natural slope may be progressive and earlier constructional work above the prevailing water level may become undermined. In such conditions a further deep toe, at a lower level, may have to be constructed with a new pitched slope carried into the original work at higher level on the bank. Fig. 1 represents a typical arrangement of protective pitching with a further arrangement of stepped pitching, Fig. 2, which may eventually be required.

A sectional diagram is also given, Fig. 3, of a concrete flume which had originally been constructed in an oblique direction across the upper levels of a reservoir to discharge below top-water level. On account of the subsequent erosion which took place in the reservoir floor, the flume became badly undermined along a considerable length, and as an interim measure, a stone pitched stiffening was built in on the reservoir side. Progressive erosion occurred, however, and the flume was finally made safe by concrete underpinning to rock surface.

Steel and Iron Work

The maintenance of steel and iron work in contact with water requires considerable attention in all hydro-electric works. This is particularly important where pressure pipe lines operating under high working heads are concerned.

It might be noted that steel is more prone to rusting than cast or wrought iron, and mild steel more so than cast steel. The chemical reaction of rusting normally leaves a hydrated ferric oxide on the metal surfaces, but where, under certain conditions, electrolytic action occurs, a more insidious form of corrosion takes place. Corrosion that is distributed uniformly on a steel surface is not usually dangerous and can generally be treated by suitable inhibiting agents. Where a steel surface is covered with an insulating layer capable of acting as a cathode and the underlying metal becomes exposed at isolated points, these places constitute points of connection with an anodic area. Progressive corrosion occurs by electrolytic action at these points, with the formation of a bulbous rust sometimes referred to as tuberculation or pitting. If neglected this condition can become serious as the bulbous spots may assume large dimensions with deep areas of corrosion below them. Corrosion of this kind has been observed to penetrate to a depth of $\frac{3}{16}$ in. into the steel. Such a depth of pitting in a pipe line under high pressure is dangerous.

Considerable difference of opinion exists on the choice of suitable covering agents to prevent rusting, but a more important matter than the actual finish applied is the proper cleaning of the steel surfaces before treatment. Unless the surfaces are properly cleaned before the application of the covering agent, the value of the treatment will be lost through the formation of further rust and corrosion. The most effective way to clean steel surfaces for subsequent painting or other covering is sand blasting, although it is expensive and in some places is cumbersome to apply. Whatever process is used, however, rust and dirt must be entirely removed before the surfaces can be considered ready for treatment, and care will require to be taken to ensure that the surface remains clean and free from incipient rusting if a time interval is necessary before the protective agent can be applied.

Less effective methods of cleaning steel surface are scraping and brushing either by hand or with a power-operated tool. In certain conditions a power-operated tool can be quite effective, but ample power is essential; the wear on the steel wire brushes will be heavy and the operator must be well protected. If wide metal surfaces are being dealt with the power driven tool is not so effective as might be anticipated.

With regard to painting agents there is much difference of opinion and various types of paints can be more or less equally effective if the surfaces are truly clean. One of the best paints for a primary coating on steel is red lead which, however, on account of its colour, is not altogether suitable for a finishing coat on outer surfaces. But this objection does not arise on the inside surfaces of pipes where, indeed, there is some advantage in a light colour finish. If red lead paint is used and it is desired to finish the work with a bituminous paint, a suitable time interval should elapse between the application of two such dissimilar base paints. It has been found that a mixed paint of red lead and iron oxide has good lasting qualities.

Bituminous paints are frequently used on steel surfaces and give good results. For the interior surfaces of pressure pipes a bituminous enamel applied hot is very effective and may have a considerable life if originally applied on clean surfaces. Care may require to be taken in making use of certain types of heavy coats of bituminous covering in that the steel surfaces so treated should not be subjected to heat which might tend to melt the coating such, for example, as might be the case in an empty pressure pipe in hot summer weather. The application of metallic coatings on steel pipes (quite apart from the use of galvanising) by the use of a heating flame is now being used for the protection of new steel pressure pipes. The coatings normally used are zinc and aluminium applied to the surfaces very lightly in one or more coats. On account of the relatively thin deposit of metal which may thus be applied the use of a paint covering over the coating metal should conduce to a longer life by the mechanical protection given to the newly metallized surface. It is particularly important that the surfaces to which a metallic coating is applied, should be perfectly clean and the use of preliminary sand blast cleaning is necessary.

The use of good galvanising on steel surfaces not under water is a very useful form of protection and has a relatively long life, but when used under water —particularly in peaty waters of high acidity and under stream flow—it is not so satisfactory. On steel pipe lines where the projecting screw threads of connecting bolts may be subject to serious damage through rusting, a coating of mixed white lead and tallow with a protective twine binding is effective. Steel wire ropes may be used in certain types of gates and hoisting structures at dams and intakes to pressure conduits, and for proper maintenance these require to be kept in a well greased condition. Screwed spindles to gates and valves must be similarly treated.

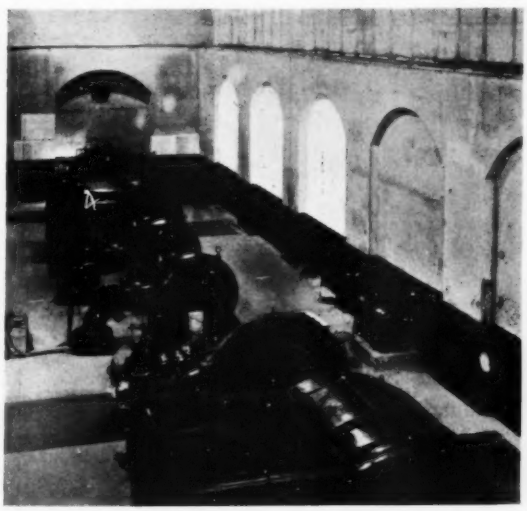
Pump Storage Systems

By A. VOSKA (Escher Wyss Limited). The second part of an article outlining the purpose of hydraulic storage and the fundamentals for successful operation.

Another example of the distribution of the discharge between several pumps is illustrated in Figs. 18 and 20, which show a tandem arrangement on much the same lines as those of the Zapello plant of the Acciaierie e Ferriere Lombarde Falek, S.A., Milan. The transmission of the 5,120 h.p. (or 2,560 h.p. output when operating with one pump only) is effected through a toothed flexible coupling which can be put in action by hand wheel. The pumps, or single pump as the case may be, must be put into gear while the set is stationary. The water flows to the four-stage pumps at a pressure between 50 and 200 ft. head; the manometric delivery head varies between 1,000 and 1,260 ft. The maximum volume of water is 108 gallons per sec. This plant is noteworthy on account of the considerable head of 1,180 ft. on the Francis turbine which, at 1,260 r.p.m., with a negative suction head of 33 to 200 ft., works as a "back-pressure turbine." Therefore, after synchronising the set, as it is not possible to empty the turbine due to its setting, it is cut out by disengaging a gear coupling. Thus, in finally taking up the drive for the accumulator, the pump and motor operate with the turbine isolated. With two sets, each of two pumps, the total accumulator capacity is approximately 10,000 h.p.

In designing any plant, especially one of large size, a decision must be made as to vertical or horizontal arrangement. As to this, no fixed rules can be laid down. Economic issues, the nature of the ground—whether rock or soft soil—must be taken into consideration. Favourable erection conditions form another factor to which regard must be paid. A primary factor in coming to a decision is the condition of the necessary feed pressure which must be met. With a high n_s this means sinking the pumps, and usually this only is possible with the vertical arrangement.

Fig. 18 (left): View of the 10,000 h.p. Zapello plant installed in underground power house
Fig. 19 (below): Provvidenza Lake with retaining wall. Content 57 million cubic feet. The power station inside the mountain is about half a mile from the lake



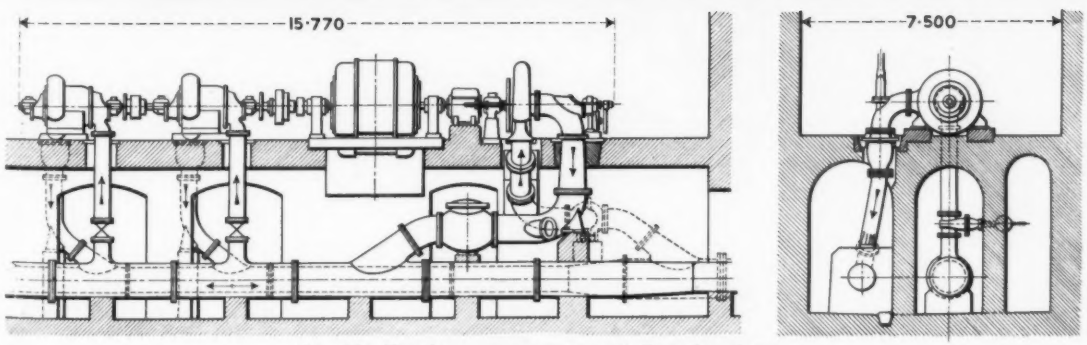


Fig. 20: Tandem arrangement of Zapello plant

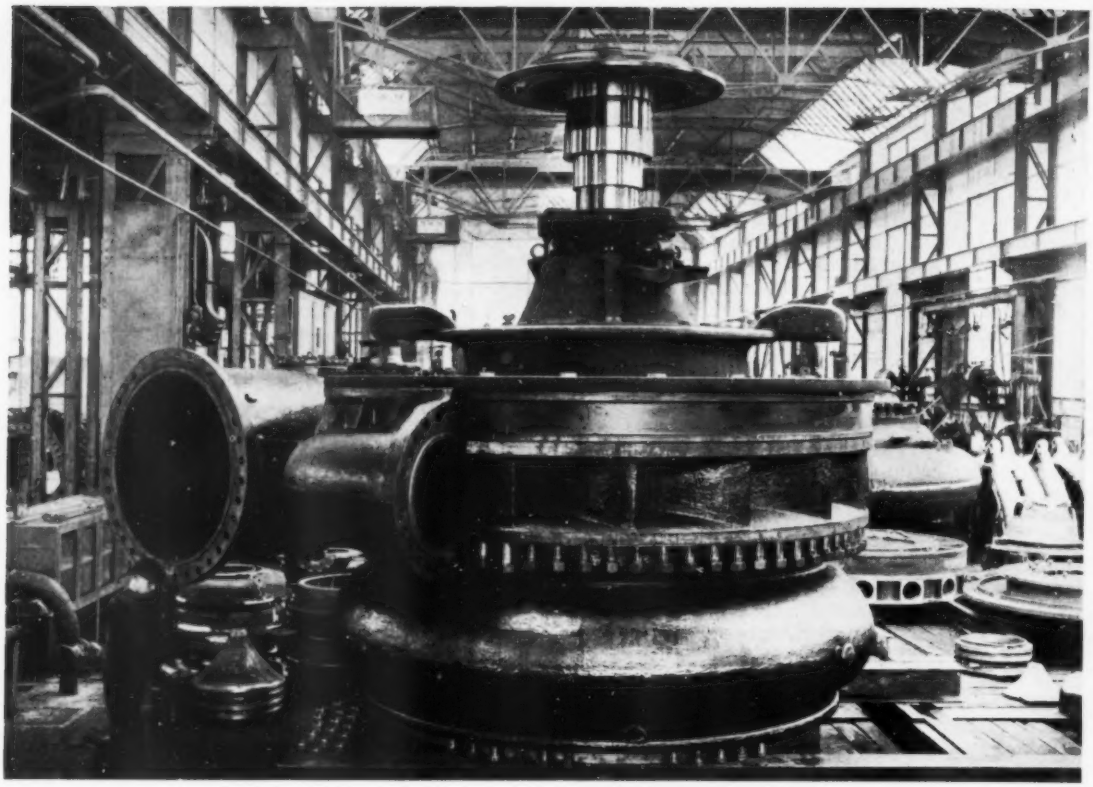


Fig. 21: Showing 24,000 h.p. Schluchsee pump

Such a plant, consisting of four sets each of 24,000 h.p. motor power, is shown in Figs. 21 and 23. This is the Schluchsee installation, half of which was supplied by Voith and half by Escher Wyss in collaboration. Each set (Fig. 23) consists of a motor generator, turbine, coupling and pump. As the pump is the most liable to cavitation it is installed in the lowest position. Each pump delivers, at 333 r.p.m., 1,700 gallons per sec. to a height of 660 ft.

At this installation, the conditions in the electrical system made a quick changeover from turbine to pump drive of importance, and arrangements had to be made to change over without stopping the turbine. To this end a hydraulic clutch was incorporated, an external view of which is shown in Fig. 23. In this there are two runners keyed respectively to the pump and turbine shafts.

The two runners operate inside a water-filled housing and the one generates sufficient head to cause rotation of the second. Once synchronous speed has been attained the purpose of the clutch is fulfilled and it has only to transmit the no-load output of the pump with the main valve closed. The transmission of the full output which follows is no longer by hydraulic means, but mechanically through a toothed crown which is first put into engagement and the clutch emptied afterwards. In this way the whole changeover to the accumulator drive is effected without stopping the set. To make this quite clear the successive steps can be set out as follows:—

1. The pump is filled with water.
2. The turbine guide apparatus is closed, and the turbine emptied, so that it runs in air; cooling water is fed to the runner seals.
3. The hydraulic clutch is slowly filled with water, displacing the air.
4. The pump gradually starts up, and when synchronous speed has been reached, the toothed crown is engaged.
5. The hydraulic clutch is now emptied and at the same time a water jet is introduced to cool the air and protect the clearances between the coupling runners.
6. The pump valve to the delivery pipe line is slowly opened and the load builds up.

In the reverse procedure, that is, to change over from accumulator to turbine drive, the delivery valve is closed, the clutch is refilled, the gear crown is disengaged and the hydraulic clutch gradually emptied. The pump is thus cut out, and by opening the turbine valve the turbine running is again put into operation. The individual clutch sequences are automatic.

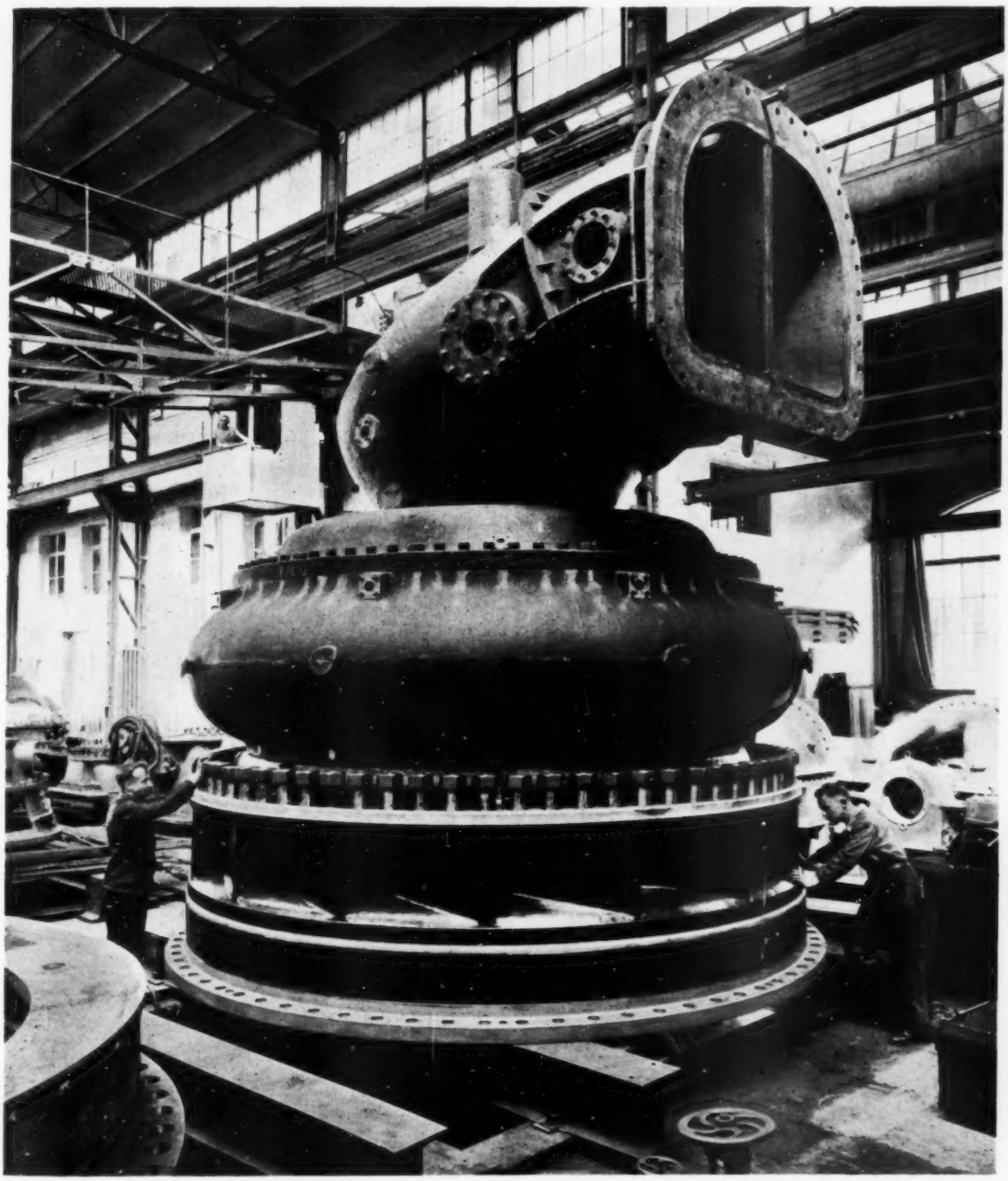
The axial thrust of the two-stage pump is taken by a thrust bearing at foundation level. A second bearing at the extreme top of the set takes the turbine thrust and the weight of the rotor.

The plant described represents the first section of a comprehensive project. In the second section at the Witznau station, four further vertical sets are installed with the four pumps supplied by Escher Wyss, each capable of taking 40,000 h.p. The general arrange-

ment follows the lines of the previous sets shown in Fig. 23. The machines are larger, however, and deliver a maximum of 2,240 gallons per sec. to a height of 820 to 900 ft. at 333 r.p.m. Here again the change-over to accumulator drive and *vice versa* occurs without stopping the turbine. As opposed to that already described, however, the clutches on these sets consist only of an impulse flow turbine runner which is designed to start up with the pump impellors turning in air. The pump casing is emptied of water immediately before starting by introducing compressed air and is then brought to full revolutions, when the gear crown is then engaged and the pump re-primed.

The hydraulic conditions on the suction side are represented by a feed head of between 31 and 87 ft. A valve, directly connected to the suction and in open position during operation, makes it possible to shut off the pump from the feed line. On the delivery side,

Fig. 22: Works photograph of the vertical, two-stage, 40,000 h.p. Witznau accumulator pump



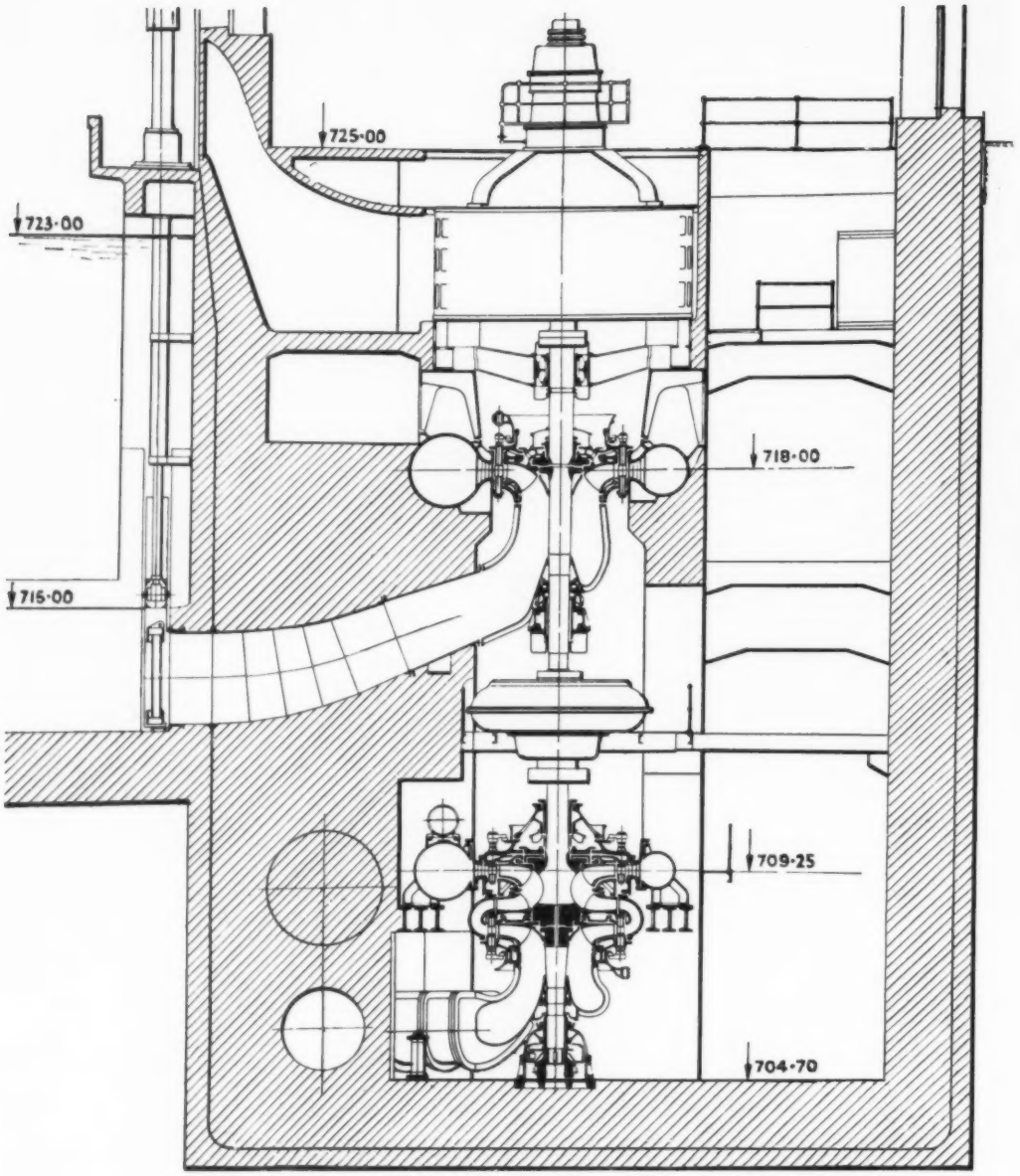


Fig. 23: Section through a vertical, two-stage 24,000 h.p. set of the Schluchsee plant

a 55 inch von Roll valve, as shown in Fig. 26, serves to shut off the delivery line.

Tests made by shutting off a single pump and then two together gave a pressure surge of 6 to 7 per cent at the foot of the pressure line, Fig. 25. The total height of the pump alone is over 24 ft; a works photograph of the two runners is seen in Fig. 30.

The idea naturally suggested itself of making the change over to accumulator drive simpler by omitting the clutch and connecting the turbine and pump shafts by means of a fixed coupling. This involves the pump running in air so that compressors and a receiver have to be employed to provide the air pressure to displace the water in the pump casing. An automatic flow governor is employed to maintain the water level in the suction pipe. The constant supply of cooling water to the glands of the runner when the turbine is in operation involves a small loss of power, but is of no significance in comparison with the gross output. A large plant of this type with four vertical Escher Wyss pumps, totalling 96,000 h.p. has been working for a number of years.

A storage plant where the direct-coupled pump also runs in air during the operation of the turbine is the "Cotilia" installation owned by the Società Terni, Italy. However, in this case the pump can be dewatered in a convenient manner by closing the suction valve. The power station comprises two horizontal

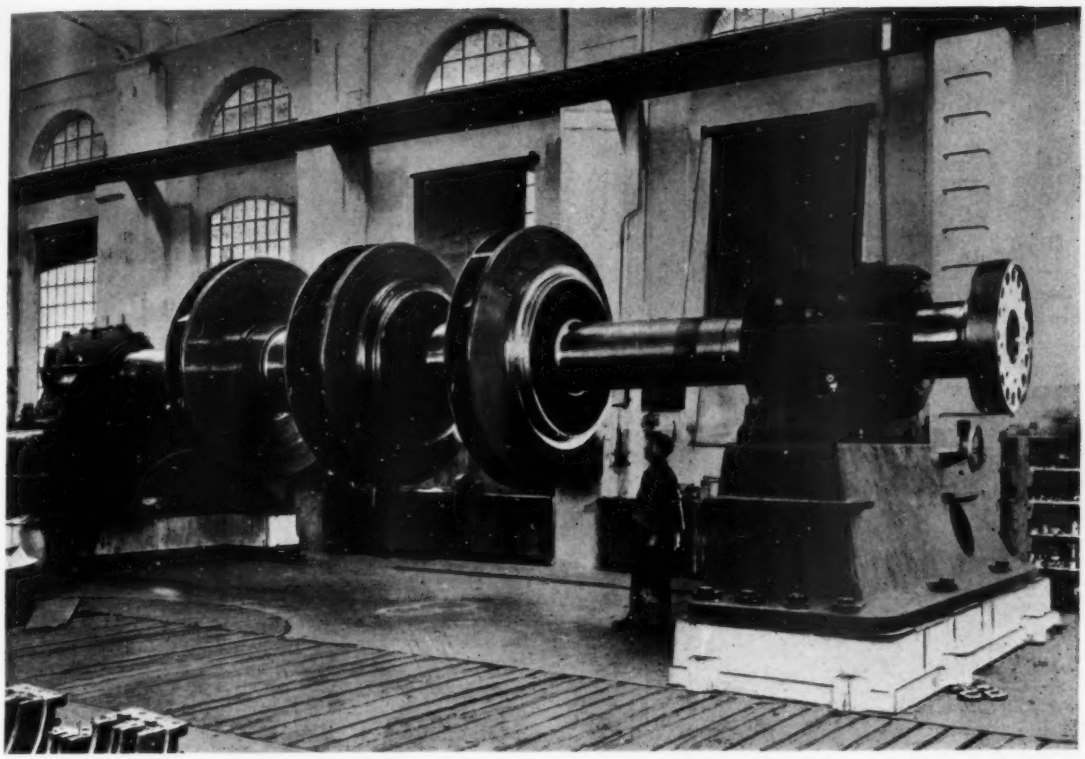
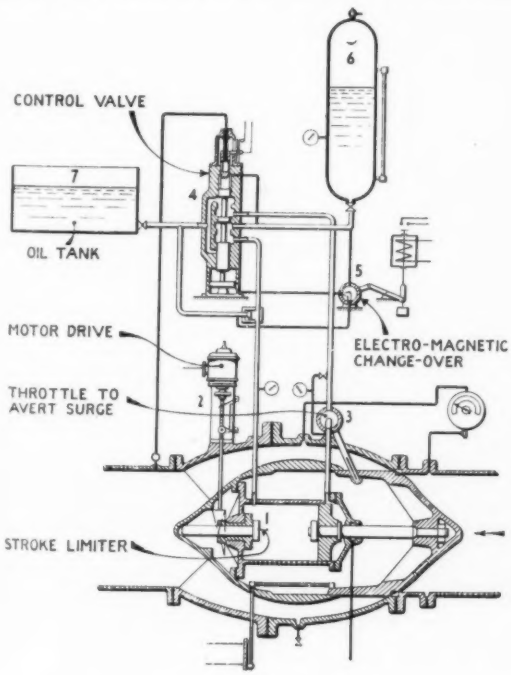
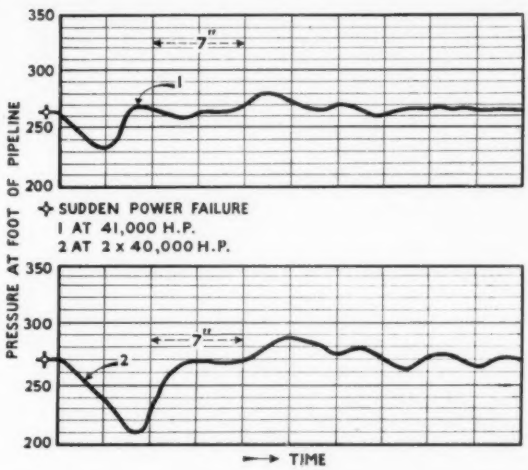


Fig. 24 (above): Runners of the Provvidenza pump
Fig. 25 (right): Shutting-off diagram of the Witznau pump
Fig. 26 (below): Diagram showing control of the quick-closing ring valve of the Witznau pump (v. Roll Klus)





sets, each of 39,000 h.p. power input, in a turbine-motor-pump-arrangement. The direct changing from turbine to pump operation, and vice versa, is effected by means of priming, or dewatering, whilst the pump is running at full speed.

Because of the conditions in the upper accumulator basin the total manometric delivery head varies greatly, and it was necessary, in view of the risk of cavitation, to limit the range of operation to between 400 and 500 ft. With heads of water under 400 ft — conditions which are actually met in practice—the von Roll ring valve, shown in the schematic diagram Fig. 29, is invaluable in maintaining a constant head

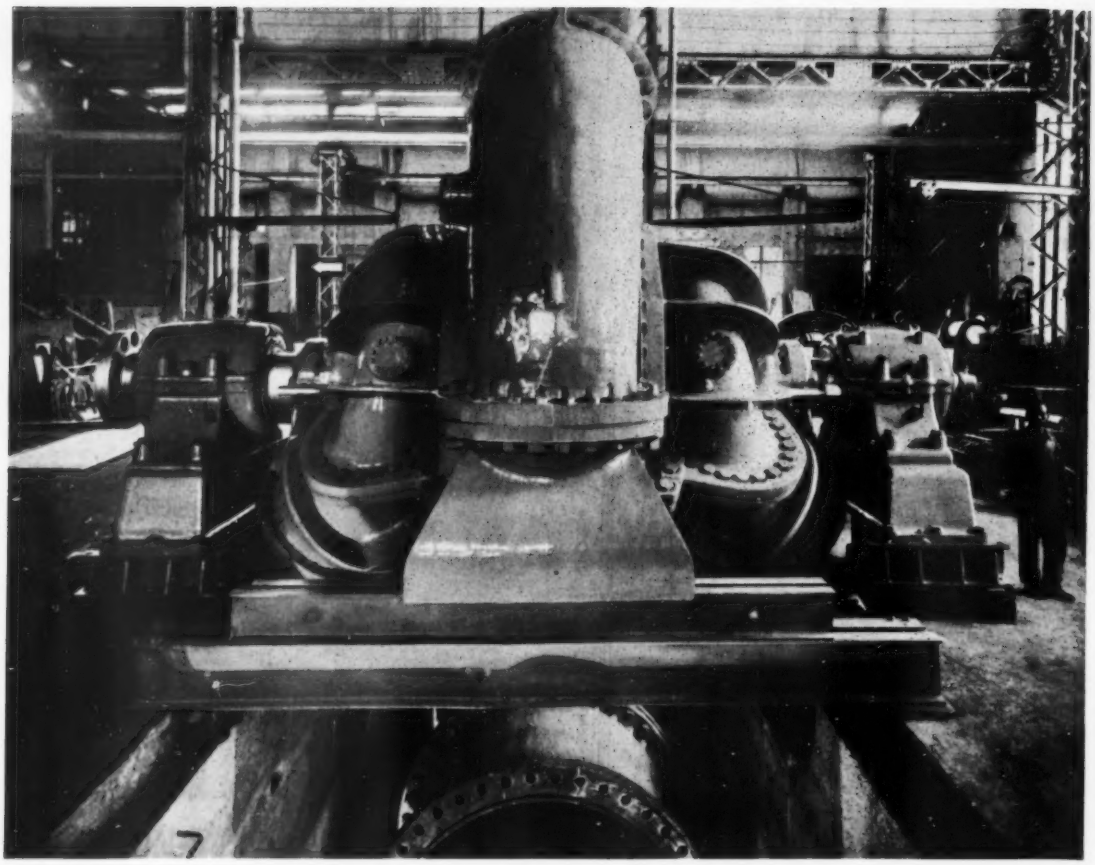


Fig. 27A: Works photograph of the 39,000 h.p. Cotilia pump

Fig. 27B: The Cotilia pumps lift water from the Vellino River; this view shows an arched pipe crossing the river to feed a turbine operating under a 100 ft. head in the same plant

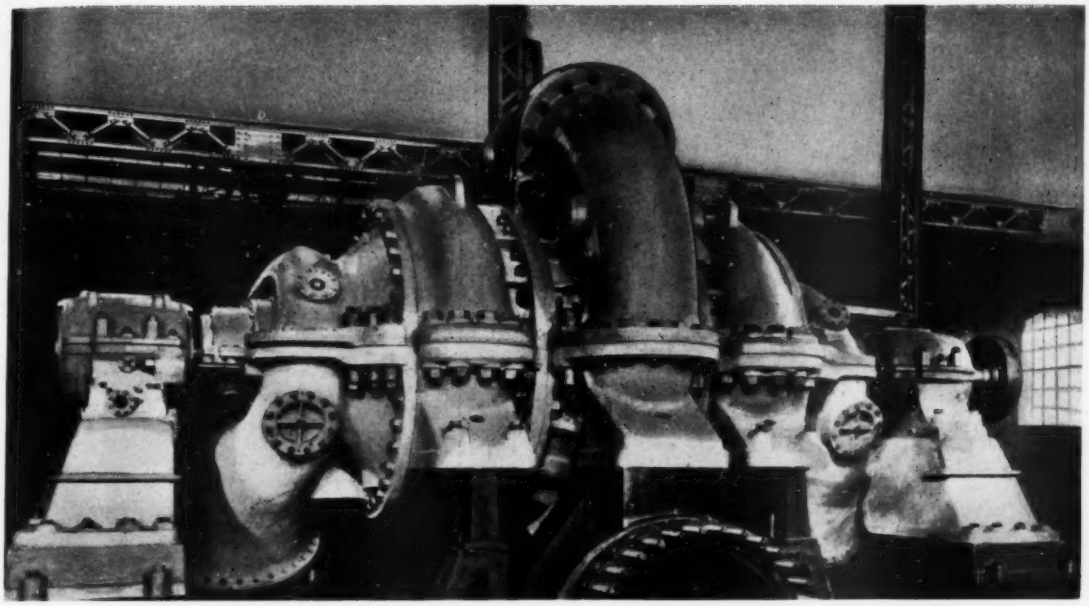


Fig. 28: Works photograph of the Provvidenza pump for 62,000 h.p. drive input (Tosi—Escher Wyss)

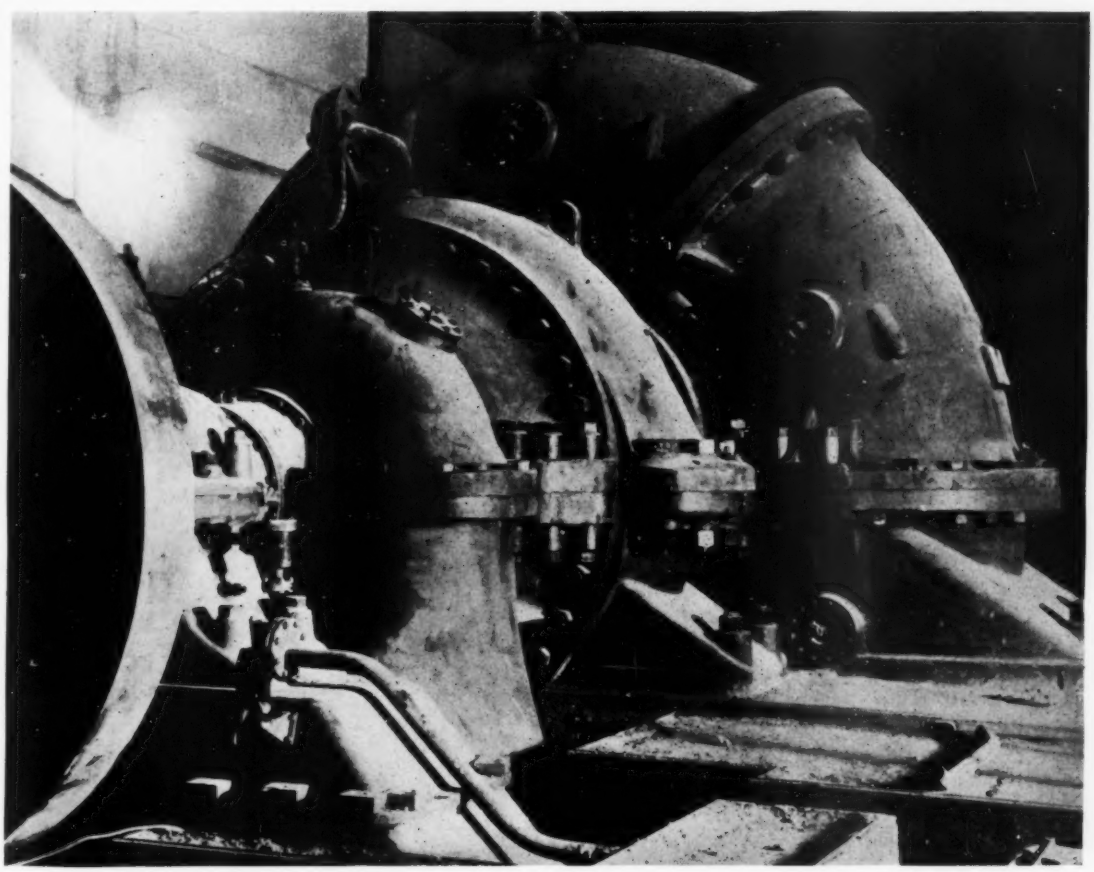


Fig. 28A: Lateral view of the Provvidenza pump

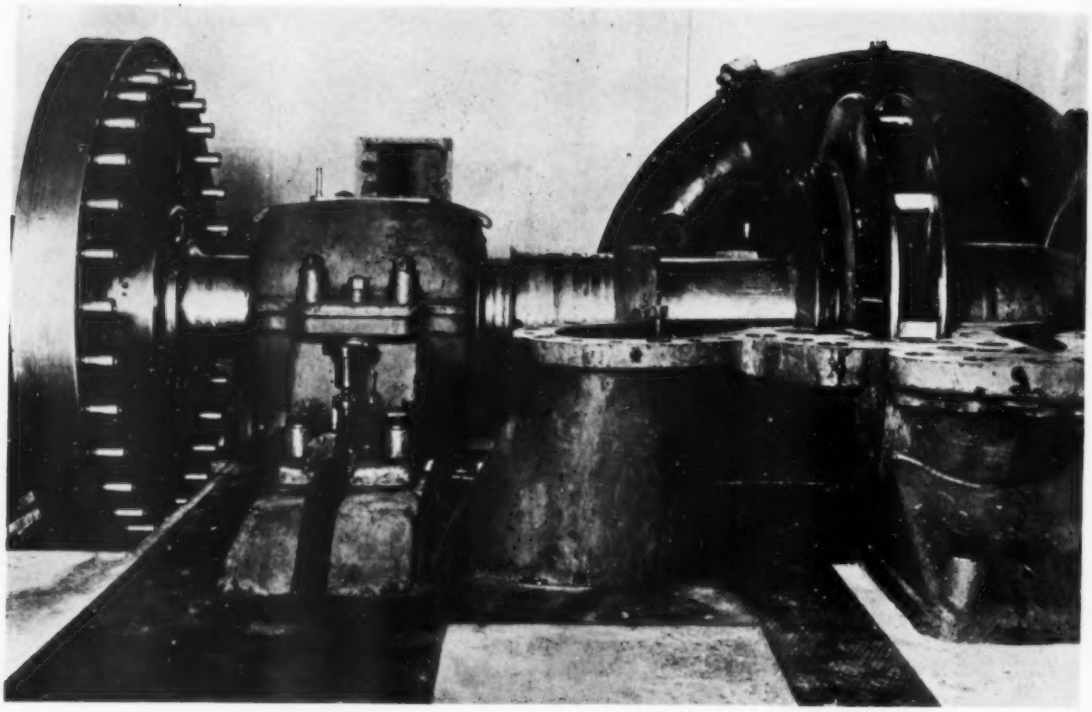


Fig. 28B: Provvidenza pump; view of first stage showing coupling

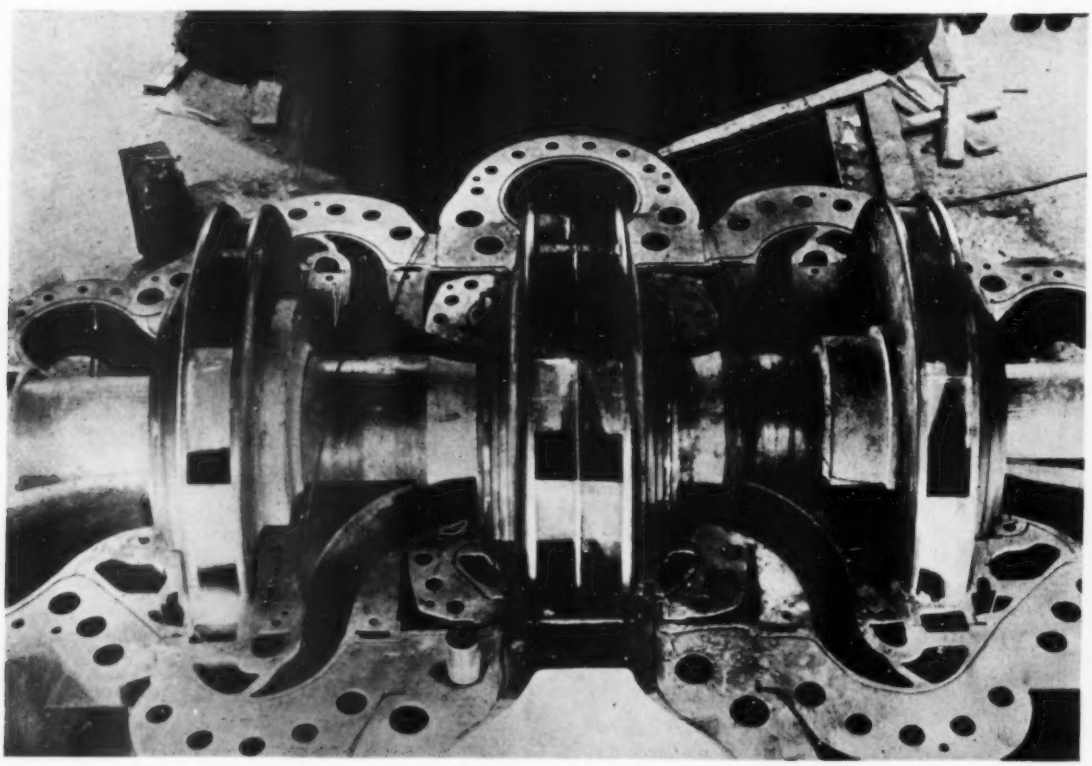
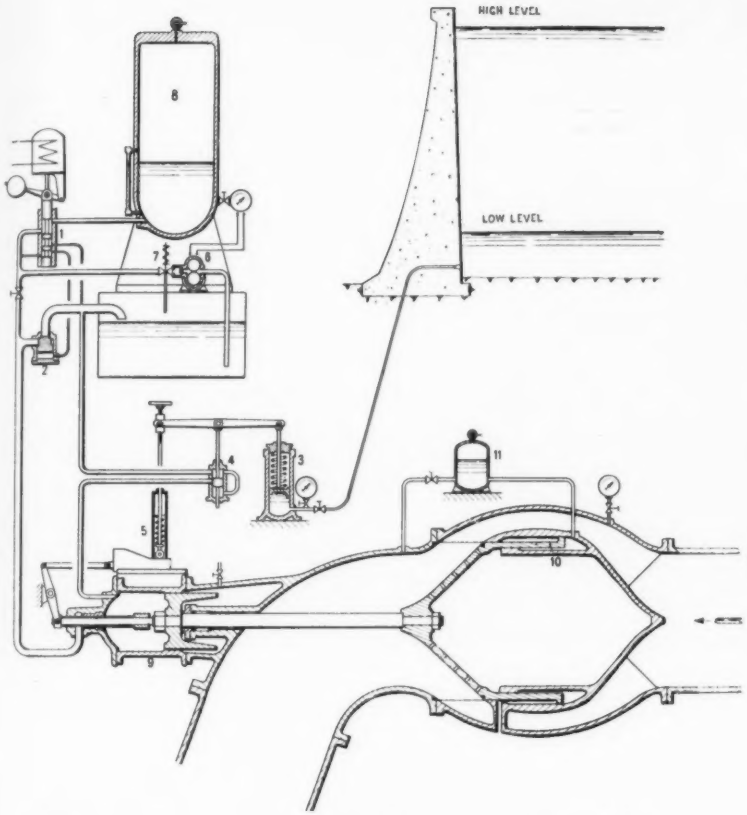


Fig. 28C: Provvidenza pump; view with upper part of casing removed to show impellers



Control:
1. Control valve electro-magnetically operated.
2. Outlet valve for quick closing.
3. Pressure relay
4. Throttle piston
5. Return-motion control.

Pumping:
6. Tooth-gear pump.
7. Safety valve.
8. Pressure water tank.

Sluice-valve control:
9. Opening servomotor.
10. Closing servomotor.
11. Air chamber acting as vibration damper.

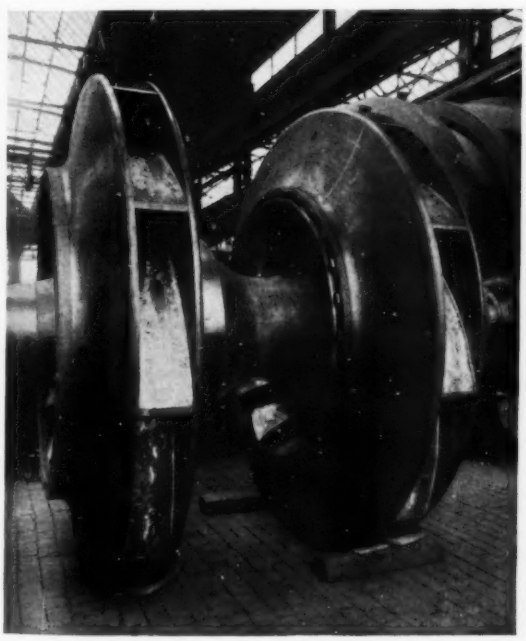
by throttling the pump. Tests taken by shutting off under various loads at this installation gave a maximum pressure surge of 6.5 per cent at the foot of the pressure pipeline. Fig. 27A reproduces a photograph taken in the Tosi works and shows this pump which was built to the design of Escher Wyss by Tosi of Legnano in conjunction with De. Pretto-Escher Wyss. The hydraulic characteristics were determined by reference to a model pump designed and built by Escher Wyss.

A hydraulic accumulator installation employing the largest plant so far built, the Provvidenza plant in Abruzzi, which also belongs to the Societa Terni, and is situated 3,380 feet above sea level, was

Fig. 29 (left): Control diagram of the quick-closing ring valve of the 39,000 h.p. Cotilia pump

Fig. 30 (below, left): Runners of the 40,000 h.p. Witznau pump

Fig. 31 (below, right): Runner of a 6,900 h.p. accumulator pump for 87 ft. delivery head. The vanes are covered with non-oxydising material at the inlet



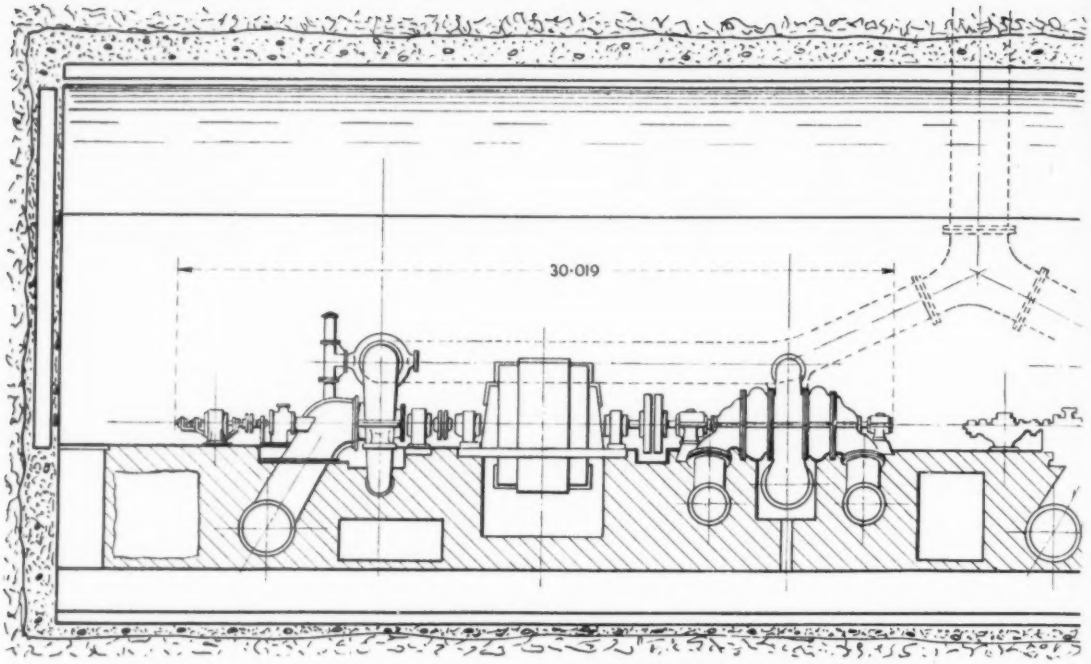
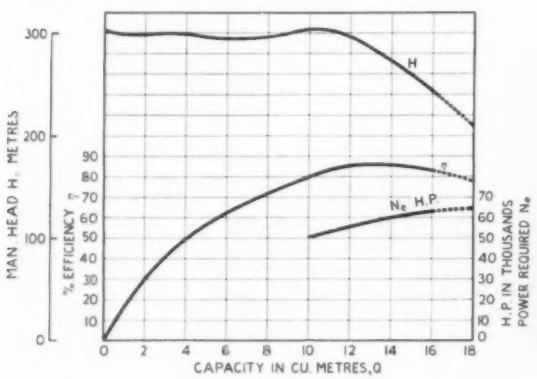
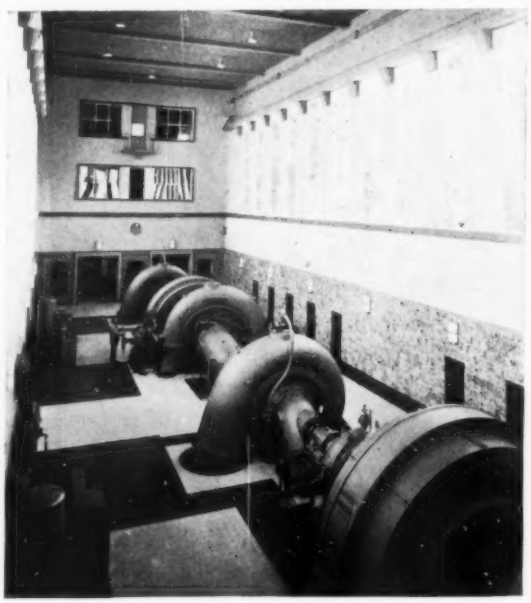


Fig. 32 (above): Sectional elevation of the Provvidenza accumulator set

Fig. 33 (below): Results of model tests of the Provvidenza pump

Fig. 34 (right): Accumulator plant with two medium pressure pumps, each for 174 ft. delivery head and 1,100 galls./sec. Drive input 4,050 h.p. each





recently started up. This equipment is housed in an underground power station at the end of a tunnel 800 yards in length, and so arranged that a second set can be installed at a later date. The pump requires a maximum drive of 62,000 h.p. and delivers 3,600 gallons per second against a 790 ft. delivery head. The set is shown in Fig. 32 and consists of the turbine, a 50,000 kVa generator, and the pump by which the water of the Provvidenza Lake (Fig. 19) is taken to the Campotosto Lake 920 ft. above and which has a capacity of 5,400 million cubic feet of water. The motor is connected by a Riva bolt coupling, the bolts of which are fixed to a pneumatically displaceable plate, so that they can be engaged in the shortest possible time with the half-coupling on the motor side. Fig. 28 shows a works photograph of this pump, which was built to the design of Escher Wyss in collaboration with Tosi. The runner and its two bearings, Fig. 24, was built by De Pretto-Escher Wyss. The hydraulic results obtained from tests on a model constructed by Escher Wyss, and converted to the full-scale construction, are given in Fig. 33.

All the pumps in the plants mentioned above, with delivery heads between 400 and 3,000 feet, are repre-

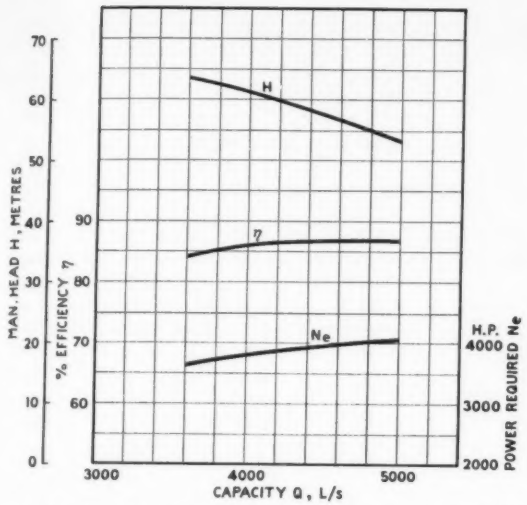


Fig. 35: Results of tests of the pumps shown in Fig. 34

sentative of current practice for high and very high pressures. Escher Wyss have also constructed plants for medium and small heads. In the power station shown in Fig. 34, two sets are installed with the normal arrangement of pump, motor-cum-generator and turbine, the pumps being designed for a 190 feet delivery head. The pumping operation is generally carried out at night but sometimes during the day, and the changeover is effected by means of a hydraulic coupling as shown in Fig. 23. The test results are given in Fig. 35. The pump delivers 1,100 gallons per second to a height of 174 ft., and this requires a drive of 4,050 h.p. The efficiency figure of 87 per cent. may be regarded as particularly high.

At another plant there is a head which is still lower, being only 87 ft. The pump must obviously be able to deal with very large volumes of water, and in the case in question, this amounts, on the average, to 3,500 gallons per second. The installation comprises two vertical sets consisting of motor and pump only. The pump runner shown in Fig. 31 is constantly immersed in water so that easy starting is assured, and a very high efficiency figure of 91 per cent. has been achieved with this design.

Some information on some detail aspects of the design of these pumps may now be offered. Usually the water is free from chemical pollution, but it sometimes contains foreign matter in the form of sand or even glacier detritus. Preliminary cleaning in a desanding plant is thus sometimes necessary, in order to prevent or to reduce the erosive action of the sand on the runners.

An essential influence which determines the life of the runner is, of course, the nature of the materials used. Cast steel, special bronze, and in particular stainless steel, have given most satisfactory service. The combination of conditions resulting from high pressures up to 1,400 lb. per sq. in., the large bore of the housing, and the need to divide the housing into several parts for transport purposes, lead to complicated problems in regard to the strength of the various portions. For these problems cast steel forms the most usual solution.

In cases where the hydraulic conditions, on account of the multi-stage arrangement of the runners, necessitate long shafts, there is also the problem of avoiding the critical speed period; in this matter the design considerations from the mechanical and hydraulic aspects are usually directly opposed to each other, and the solution can only be found by providing a sufficiently large margin between critical and working speeds.

The first part of this article, which is concluded here, was published in the July/August issue.

EUCLIDS FOR STERLING

An important move to overcome the difficulties of dollar expenditure has been taken by the Euclid Road Machinery Company, of Cleveland, Ohio, U.S.A., which has established a factory in the British Isles for the production of Euclid earth-moving equipment within the sterling area. The new company, known as Euclid (Great Britain) Ltd., has its works and offices in Glasgow, Scotland. Approximately one million dollars have so far been invested by the American parent company.

It is anticipated that the first Euclid rear dump wagons (Model 27FD) will come off the production line at the rate of 12 a month during the first quarter of 1951, rising to approximately 24 a month for the second quarter and 30/50 a month thereafter. Meanwhile exhaustive tests are being made under severe site conditions to investigate suitable types of British-built Diesel engines for use with Euclid equipment. It is the intention of Euclid (Great Britain) Ltd. eventually to build the full range of Euclid heavy earth-moving equipment, including the bottom dump, tractor and scraper models.

Euclid earth-moving equipment built in Britain will, therefore, be available for markets all over the world.

John Blackwood Hodge and Company, of London and Northampton, and their associated companies represent the Euclid Road Machinery Company of America and Euclid (Great Britain) Ltd. in 23 countries throughout Europe, Africa, Australasia and Asia, all of whom maintain sales offices and complete maintenance depots for after-sales service.

The Brush Group has acquired an interest in the Switchgear and Erection Company (Pty.) Limited, of Germiston, Johannesburg. The company has been reformed and its title is the Switchgear and Engineering Corporation of South Africa (SECOR). Technical and design facilities of the Brush Group will be at the disposal of the new corporation and technical assistants will be provided as necessary from England.

The existing directors of Switchgear and Erection (Pty.) Limited are joining the new board and the management will remain unchanged. Mr. L. H. L. Badham will continue as managing director and Mr. Joseph White, chairman and managing director of Brush (S.A.) Limited, together with Mr. Sydney A. Lane, an executive director of the Brush Electrical Engineering Company in England, are joining the board of SECOR.

From the Journals of the technical institutions and other material published in the Press of the World

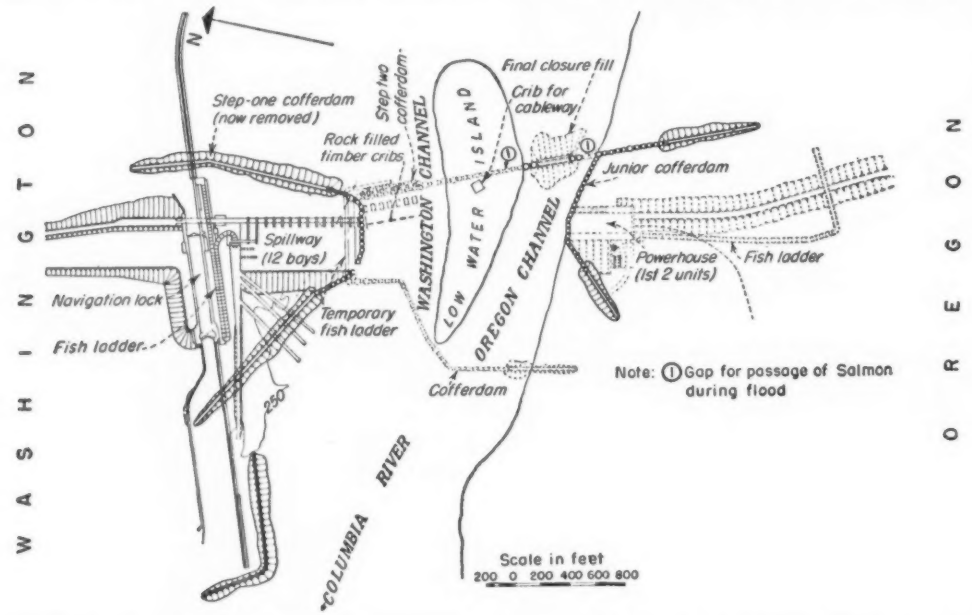
Taming the Columbia River at McNary Dam

Final work is under way to prepare for what promises to be a spectacular construction feat—the diversion of the Columbia River at McNary Dam. To close the upstream part of the second-stage cofferdam, the entire flow of the river must be forced through twelve low blocks in sections of the spillway, each 50 ft. wide, built within the first-stage cofferdam. The job is rendered particularly difficult by the fact that the lowest flows to be anticipated are within the range of 75,000 to 100,000 cu. ft. per second, while, on the other hand, the final closure must be made against a 17 to 20 ft. head in a rock channel 40 to 60 ft. deep at low water. Partly because of the big floods in the late autumn, winter and spring, and partly because of the spring run of Chinook salmon which rules out a closure in August or September, early October is the only time that seems safe to start the final closure, an operation which may take as much as two months.

One of the initial steps was to divide the Washington channel (about 20 ft. deep) by eight heavy rock-filled timber cribs, each 30 by 60 ft., accurately fitted to the rough bottom and designed to withstand heavy ice and flood conditions. It is also planned to drop concrete stop logs in front of the cribs, to allow steel pile cells to be driven upstream in quiet water. The island between the Washington and Oregon channels is swept by floods in spring and early summer; this section will be blocked, after the floods, by sheet pile cells built in the dry. Astride the 240 ft. wide Oregon channel two sets of two cells each have been placed behind temporary rockfills. The gaps shoreward of these cells are now left open for the passage of salmon, and will be filled by sheet pile cells prior to the final closure. Work already done inside the Washington shore or step-one cofferdam includes the twelve spillway bays, the navigation lock and the fish ladders. On the Oregon shore a "junior" cofferdam abuts the deep water channel. This permits an early start on portions of the powerhouse so as to enable generating units to be placed on the line as quickly as possible.

The final closure will be effected by means of heavy rock, tests having proved that this method is the safest; 8-ton tetrahedrons, precast of low grade concrete, will be placed at critical portions of the channel, while the fill in areas not subject to the highest water velocities will be made of rock. Assuming a river flow of 100,000 cu. ft. per second and a downstream slope of 1 in 2, the maximum velocity across the crest of the fill will be 19 ft. per second with a head differential of 9 ft. The tetrahedrons are expected to be stable under such velocity conditions. A sufficient number of tetrahedrons will, however, be provided to meet more severe conditions and allow for possible movement and a resulting flatter slope.

Since the highest velocities will occur on the



downstream slope, it is planned to spread the tetrahedrons in the lower layers well downstream. The upstream portion of the fill will be made of as large rock as available. The procedure will be: place a dyke of tetrahedrons, fill upstream from that with a rock blanket almost up to the crest of the dyke; place another dyke or layer of tetrahedrons, then more rock. All these materials will be placed from a movable cableway. This rock work is to be done, according to contract, within 60 days but is expected to be completed in a considerably shorter time to avoid flood hazards.

When closure of the upstream leg is accomplished the main "second step" cofferdam will be completed by a downstream leg 26 ft. lower than the upstream leg. This cofferdam will be overstopped by any flow over 386,000 cubic ft. per second, and is expected to be flooded at least once during the construction of the dam and power house. Temporary fish ladders must be provided to allow the escape of any salmon trapped in this cofferdam as a result of such a flood.

The McNary power house will have an ultimate installed capacity of 980,000 kW (fourteen 70,000 kW units), and will meet peak loads up to 1,127,000 kW; there will be provision for six additional units, if required. According to present schedules the first two units are to be on the line by Dec. 1, 1953. Construction work is under way inside the junior cofferdam on the substructure for units 1 and 2, and the assembly and station service bays. Contract plans are being prepared for the substructure for units 3 to 14, and the complete superstructure.

The size of the equipment to be installed is noteworthy. By selecting low-reactance-type generators, one transmission line will be saved but the generators will perhaps be the largest in the world. The rotor diameter will be 36 ft., the overall diameter 57 ft., and the weight will be 600 tons.

The six-bladed Kaplan-type turbines will also be gigantic. The runners and shafts will each weigh 345 tons, and the estimated shipping weight for each turbine exceeds 1,100 tons.

In terms of concrete McNary will be about the eighth or ninth largest dam to be constructed in U.S. (1,850,000 cubic yards); in the amount of steel used, however, it is believed that this dam breaks all records, 131,000 tons in total—about three times as much as required for a modern battleship. (Col. William Whipple, "Engineering News-Record," Vol. 144, No. 26, June 29, 1950. p. 29, 4 pp., 4 ff.).

How China Builds a Dam

Before going to China as technical adviser and chief geologist of the National Hydroelectric Engineering Bureau, Mr. Fred O. Jones was in charge of the geological investigations connected with the Grand Coulée Dam project. In this article Mr. Jones describes the methods of construction he witnessed as the first unit of the Yangtse River Basin development, the Upper Tsing Yuan Tung dam, got under way. Located in the great inland province of Szechvan, the dam site spans the valley of the Lung Chi Ho, a small tributary of the Yangtse, 25 miles above its confluence with the Yangtse 1300 miles above Shanghai. This dam (40 ft. high, 650 ft. long, with an estimated volume of 700,000 cubic ft. of masonry) is being constructed by methods as ancient as those used to build China's Great Wall, and the Pyramids of Egypt. Except for an air compressor, a small number of pneumatic hammers and drills, and a few other pieces of mechanical equipment, driven by a small amount of power available at a plant near Chamgshow, the dam is being built literally stone upon stone by hand.

The entire floor at the dam site is good, hard sandstone, the river having scoured the valley nearly clean of soil materials. The stream being very small during the low water season, diversion for construction was quite simple; while work was in progress along one section of the valley floor, the river was confined in another section by temporary cofferdams of stone blocks or bamboo baskets tamped full of clayey soil. The bedrock along the floor was excavated by hand to a depth of 6 to 10 ft. to remove all the decayed and disintegrated rock. Blast holes were drilled with hammers and steel points for loosening the bedrock, and the large blocks were broken into pieces small enough to be carried away by "yoyo" sticks or in baskets. The foundation rock was then trimmed smooth and carefully cleaned with brushes in preparation for laying the stone blocks of the dam. Keyways for the dam were excavated for a distance of 30 to 40 ft. into the shale abutments on the sides of the valley.

The dam will require 120,000 stone blocks each measuring approximately 16 in. x 16 in. by 2 ft. 8 in. to 3 ft. 10 in., and weighing 600 to 800 pounds. These blocks are worked to the required size from larger blocks cut from boulders, dislodged chunks, and outcropping ledges, first by chiselling a row of holes and then driving a series of wedges until the rock split. In many places families work together, the lightest work (final dressing and sizing) being done by old men and children. Most of the blocks are carried from their many places of origin by coolies, a few being transported to the dam site by push-cars on narrow gauge railways constructed on a light downgrade from the quarries. In one place a slide was improvised by using wooden sleds on rails down a steep gradient; the sleds were carried back up the hill after each load of two blocks was sent down.

Fifteen hundred workmen were employed on the dam. Most of them were regarded as skilled or semi-skilled, and no one who has seen them at work would say they are unskilful.

The blocks were fitted together closely with thick cement grout. After each layer had been placed, the surface was dressed smooth and thoroughly cleaned before placing the next layer in order to minimize the use of cement and insure a good bond between layers. An electric half-yard mixer mixed that part of the grout not prepared by hand, the aggregate being fed in by boxes and baskets of measured sizes, and water added with a wooden ladle. Open-end scooplike baskets were used to carry the mortar to all parts of the job.

Work done under contract (more than 90 separate contracts were let) was actively supervised by the engineering staff. Many of the early con-

tractors disappeared over night as soon as they felt they were losing money but became more dependable after the practice was adopted of holding 10 per cent. of their money back.

In conclusion the author asks:—"When will the Upper Tsing Tung dam be completed?" The answer is:—"I don't know." (Fred O. Jones, "The Reclamation Era," Vol. 36, No. 5, May 1950, p. 85, 4 pp., 10 ff.).

New Unit for Old Hydro Plant

This article describes a rather uncommon method which was put into application at the Cheoah dam on the Little Tennessee River, in North Carolina, in order to increase the peak-load power of a 30-year-old plant. To the three sets which this plant had at the outset, a fourth was added in 1925, all four sets being fed by a 27 ft. dia. tunnel which runs 450 ft. from above the 750 ft. long dam to a point abreast of the power house where it divides into four parallel tunnel-type penstocks 13 ft. 6 in. in diam. The head is 188 ft. Flood waters coming down the narrow gorge used to flow over the 230-ft. high spillway dam; in order to reduce flood two further dams have been built upstream. In addition the Tennessee Valley Authority now load-dispatches the Cheoah development, and co-ordinates its output with the peak-load operation of the upstream plants.

In order to fit the Cheoah plant better into this system of water and power regulation it was decided to increase the capacity of the power house by one third (30,000 kW) by the addition of a fifth generating set. The installation of the added capacity was marked by simplicity. No tunnelling was done; the dam suffered but little alteration; a new type of trash rack was developed; and the original lines of the power house were preserved, even though the added unit is larger than the old ones. Originally there were 20 flood gates, each with a steel tainter gate for control; the southernmost of these gates has been converted into an intake for the new set, and has now a fixed-roller, gravity-operated intake gate installed inside a gatehouse on the top of the dam, and controlled from the power house below.

As the installation of a trash rack of the conventional type in front of the intake would have involved a radical alteration of the top of the dam, the designers worked out a basket type trash rack—a semi-decagon of grating—that hangs on the upstream face of the dam at the new gate house and efficiently protects the intake of the new unit. This trash rack is within range of the stationary derrick crane which attends to the nearby tunnel intake of the old generating sets; it is therefore quite easy to lift it on to the top of the dam for cleaning and painting. In plan the new rack is five-sided in shape; it measures 31 ft. along the face of the dam, 14½ ft. upstream from the face, and its five vertical sides are 28 ft. in height. The steel structure is all welded, and has an open area of 1,100 sq. ft. The grating consists of 0.25 x 4-in. vertical bars 4.75 in. apart, with inside horizontal bars 2 ft. 3.25 in. apart; the bottom grating is a similar grid. The steel framing at the top of the rack supports an open timber decking placed in cobweb design; this decking is accessible from the top of the dam. The basket trash rack has proved highly satisfactory under the conditions obtaining at the Cheoah dam.

Only minor concreting was needed at the crest of the converted overflow spillway to give it the curvature required for the intake flow. The penstock itself starts out as a 17 ft. dia. concrete conduit running down the face of the dam. It runs some 57 ft. at a 12 on 8 slope, then curves into a 1 in 2.64 slope for the remaining 55 ft. of its concreted portion. The rest is all welded steel, 17 ft. in dia. for 272 ft. and 16 ft. in dia. for 103 ft. of its length. The spiral casing, too, is all welded, no rivets being used. Casing and penstock were delivered to the job in shaped sections, and subsequently welded on the spot.

To house the new set the power house had to be lengthened by 71 ft. 6 in. Owing to the scarcity of steel supplies at the time, reinforced concrete framing was used. The new section was made no wider than the old, but instead of a 6-ft. thick foundation wall, pilasters and curtain walls were poured to give maximum interior space around the larger unit. The turbine was set lower than the old units and the generator was set close down on it so that overhead clearances would be no problem. Outside the building's new end, an entirely independent switch-yard, with all-aluminium structures, was built to serve the new unit. In fact the new unit is independent in every respect of the four old ones, so that the Cheoah development has now two distinct sources of power, each capable of operating without the other. This means that the old tunnel, in constant use since 1919, can now be unwatered and inspected while the new fifth unit continuously puts out 30,000 kW. The old gates at the tunnel intake have never been serviced. Except for short shut-downs on two consecutive Sundays for making high-tension connections, the new generating unit went on the line without disturbing the output of the plant. ("Engineering News-Record," Vol. 144, No. 25, June 22, 1950).

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